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APPARENT VISCOSITY OF COAL-OIL SLURRIES

by

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A THESIS

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ABSTRACT

The viscosities of coal-anthracene oil and coal-bitumen slurries have been measured at atmospheric pressure, at temperatures up to 150°C, and with coal loadings up to 50% by weight. These measurements were performed using a Couette type Haake Rotoviscometer. The effects of varying shear rate, temperature, and coal concentration have been correlated with Newtonian and power law fluid models, an absolute rate theory, and the classical theories of suspended particle slurries, respectively.

The results obtained indicated that the slurries behaved as Newtonian fluids at lower coal concentrations. Increasing coal loadings caused an increasing non-Newtonian pseudoplastic behaviour of the slurries. The viscosity-temperature dependence may be modelled using the theory of absolute rates. The viscosity-coal concentration dependence may be correlated using classical theories of suspended particle slurries, but the effect of coal concentration on slurry viscosity was greater than that for slurries reported in the literature.

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TABLE OF CONTENTS

		PAGE
1.	Introduction	1
	1.1 Objectives	1
	1.2 Viscosity Models and Measurements with a Couette Viscometer	2
	1.3 Slurry Viscosity Models - Survey of Theoretical Work	13
	1.3.1 Solids Concentration Effect	13
	1.3.2 Temperature Effect	15
	1.4 Survey of Previous Experimental Work	18
	1.5 Experimental Apparatus and Procedure	30
2.	Results and Discussion	37
	2.1 Coal-anthracene Oil Slurries	37
	2.1.1 Shear Rate Behaviour	37
	2.1.2 Temperature Behaviour	45
	2.2 Coal Bitumen Slurries	50
	2.2.1 Shear Rate Behaviour	50
	2.2.2 Temperature Behaviour	55
	2.3 Coal Concentration Effect	61
3.	Conclusions and Recommendations	68
4.	References	70
	Appendix A - Coal Particle Size Distribution	74
	Appendix B - TGA Curves for Coal-Bitumen Slurries	76
	Appendix C - Data	80

LIST OF TABLES

		PAGE
Table 1.1	Haake Viscometer - Physical Data	30
Table 1.2	Laboratory Analysis of Coal, Anthracene Oil and Bitumen	34
Table 1.3	Experimental Variables	35
Table 2.1	Power Law Parameters - Coal-Anthracene Oil Slurry	44
Table 2.2	Coal-Anthracene Oil Slurry Activation Energy of Flow	48
Table 2.3	Power Law Parameters - Coal-Bitumen Slurry	56
Table 2.4	Coal-Bitumen Slurry Activation Energy of Flow	59
Table 2.5	Values of K for Reduced Viscosity Versus Coal Concentration Data	64

LIST OF FIGURES

		PAGE
Figure 1.1	Couette Viscometer Configuration	3
Figure 1.2	Special Design of Viscometer Inner Cylinder	10
Figure 1.3	Typical Haake Viscometer Output	32
Figure 2.1	Shear Stress versus Shear Rate Plot - Anthracene Oil	39
Figure 2.2	Shear Stress versus Shear Rate Plot - 10 wt% Coal-Anthracene Oil Slurry	40
Figure 2.3	Shear Stress versus Shear Rate Plot - 30 wt% Coal-Anthracene Oil Slurry	41
Figure 2.4	Shear Stress versus Shear Rate Plot - 50 wt% Coal-Anthracene Oil Slurry	42
Figure 2.5	Coal-Anthracene Oil Slurry - Apparent Viscosity versus Inverse Temperature Plot - Heating	46
Figure 2.6	Coal-Anthracene Oil Slurry - Apparent Viscosity versus Inverse Temperature Plot - Cooling	47
Figure 2.7	Shear Stress versus Shear Rate Plot - Bitumen	51
Figure 2.8	Shear Stress versus Shear Rate Plot - 10 wt% Coal-Bitumen Slurry	52
Figure 2.9	Shear Stress versus Shear Rate Plot - 30 wt% Coal-Bitumen Slurry	53
Figure 2.10	Shear Stress versus Shear Rate Plot - 50 wt% Coal-Bitumen Slurry	54
Figure 2.11	Coal-Bitumen Slurry - Apparent Viscosity versus Inverse Temperature Plot - Heating	57
Figure 2.12	Coal-Bitumen Slurry - Apparent Viscosity versus Inverse Temperature Plot - Cooling	58

PAGE

Figure 2.13 Reduced Viscosity versus Coal Concentration Plot - Low Temperature 62

Figure 2.14 Reduced Viscosity versus Coal Concentration Plot - High Temperature 63

Figure 2.15 Absolute Viscosity of Common Fluids 67

NOMENCLATURE

A	system constant
a	a constant
B	system constant
b	a constant
C_v	volume concentration
C_w	weight concentration
c	a constant
D	shear rate
d	width of gap
$\frac{dv}{dr}$	tangential shear rate
F*	standard free energy of Activation for Flow
ΔH	activation energy of viscosity
h	depth of immersion
h	Plank's constant
K	flow consistency index
K	Einstein Equation Constant
K1, K2	constants
M	Torque
N	Avogadro's number
n	flow behaviour index
R	Universal gas constant
R_i	inner cylinder radius
Ro	outer cylinder radius
r	radius
r^2	correlation coefficient
T	temperature

V	molar volume
Vi	peripheral velocity of inner cylinder

GREEK SYMBOLS

ϕ	volume concentration
η_{rel}	reduced viscosity
Ω, ω	angular velocity
μ	viscosity
μ_a	apparent viscosity
μ_{eff}	effective viscosity
μ_o	viscosity of suspending fluid
ρ	density
τ, τ_{xy}, τ_{R_θ}	shear stress
$\frac{\partial v_x}{\partial y}$, $\frac{\partial v_\theta}{\partial r}$	shear rate

1. INTRODUCTION

1.1 Objectives

The viscosity of coal slurries is one of the most important physical parameters required for the efficient design of coal liquefaction processes and equipment. The objective of this work was to quantify the viscosity of the two coal oil mixtures currently used in liquefaction research in Alberta. These slurries were mixtures of pulverized coal and anthracene oil, a product of coal coking process, and bitumen from Alberta's oil sands.

Three variables which affect slurry behaviour were investigated. These variables were shear rate, temperature, and coal concentration. The effects of these variables on slurry viscosity were to be quantified and then correlated with known models wherever possible. The ultimate goal of this work was to attempt to arrive at a correlation which would incorporate these variables and could be used to predict the viscosity of coal slurries made with these two solvents.

1.2 Viscosity Models and Measurements with a Couette Viscometer

In this work two models were used to correlate the shear rate to shear stress data produced by the instruments.

The first model used was the Newtonian fluid model:

$$\tau_{xy} = -\mu \left[\frac{\partial v_x}{\partial y} + \frac{\partial v_y}{\partial x} \right] \qquad (1.1)$$

Where:

τ_{xy} = shear stress, [Pa]

μ = absolute viscosity, [Pa.s]

$\frac{\partial v_x}{\partial y}$ = shear rate in y-direction, [s^{-1}]

$\frac{\partial v_y}{\partial x}$ = shear rate in x-direction, [s^{-1}]

Measurements in this study were performed using an instrument that was calibrated, assuming one dimensional, laminar, Newtonian Couette flow, see Figure 1.1 therefore equation (1.1) becomes, in cylindrical coordinates,

$$\tau_{r\theta} = \mu \left[\frac{-dv_\theta}{dr} \right] \qquad (1.2)$$

The other model used to correlate data was a two parameter power-law model, which is formulated as:

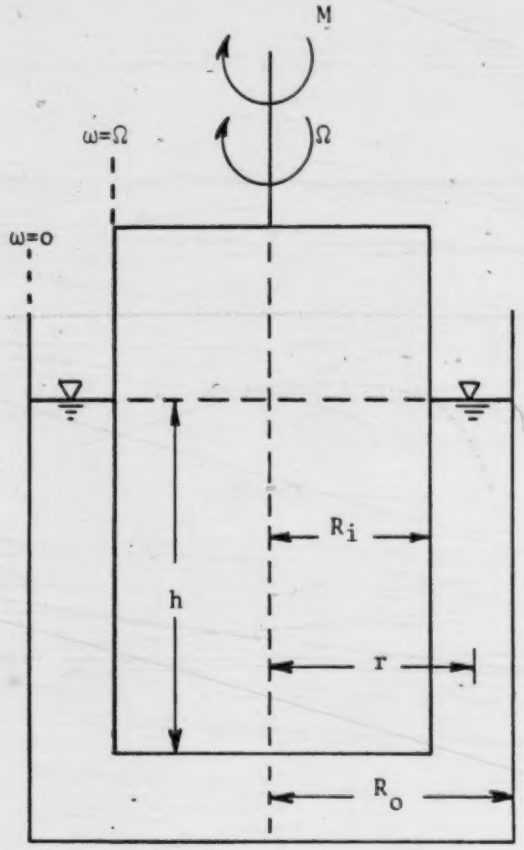

Figure 1.1 Couette Viscometer Configuration

$$\tau_{r\theta} = K \left| \frac{-dv_\theta}{dr} \right|^n \qquad (1.3)$$

Where:

$\tau_{r\theta}$ = shear stress, [Pa.s]

K = flow consistency index, [Pa.s $^{1/n}$]

n = flow behaviour index

$\frac{dv_\theta}{dr}$ = shear rate, [s^{-1}]

From equation (1.3) a relationship describing an apparent viscosity can be developed:

$$\mu_a = K \left| \frac{-dv_\theta}{dr} \right|^{n-1} \qquad (1.4)$$

Where:

μ_a = apparent viscosity, [Pa-s]

The apparent viscosity in equation (1.4) is similar to the Newtonian or absolute viscosity in that it is the ratio of shear stress to shear rate measured by the instrument.

For the instrument used in this study, see Figure 1.1, the physical quantitities which were measured were the torque, M, and the angular velocity, Ω, applied to the inner cylinder. Therefore, there must be some way to relate these measured quantities to the shear rate and shear stress developed in the fluid. These relations must

be found in order to determine the particular model parameters, (i.e. absolute viscosity, or flow consistency index and flow behaviour index, that will be required to classify the fluid).

For the steady, incompressible, one dimensional, laminar flow of a fluid in the instrument shown in Figure 1.1 for which one also assumes a no slip condition at the wall and that the end effects are negligible the shear stress at the inner cylinder can be calculated from a simple force balance.

Torque = Surface Area x Shear Stress x Radius

$$M = 2\pi R_i h \times \tau_{r\theta}\Big|_{r=R_i} \times R_i \qquad (1.5)$$

Therefore, for any fluid staisfying the above assumptions the shear stress at the wall of the inner cylinder can easily be determined knowing the input torque, M, and the physical dimensions of the instrument.

For a Newtonian fluid an analytical solution of the Navier Stokes equations is possible for Couette flow [43]. From this solution it is possible to derive a function for the rate of shear across the gap between the two cylinders:

$$\frac{dv_\theta}{dr} = \frac{2\Omega}{r^2} \frac{R^2_i R_o^2}{R_o^2 - R^2_i} \qquad (1.6)$$

Where:

$\frac{dv_\theta}{dr}$ = shear rate, $[s^{-1}]$

Ω = angular speed of the inner cylinder, [rad/s]

R_o = radius of outer cylinder, [m]

R_i = radius of inner cylinder, [m]

r = radius, [m]

At the inner cylinder equation (1.6) becomes:

$$\left.\frac{dv_\theta}{dr}\right|_{r=R_i} = 2\Omega \frac{R_o^2}{R_o^2 - R_i^2} \qquad (1.7)$$

Thus, for a Newtonian fluid the shear rate at the inner cylinder can also be easily determined if the angular speed of inner cylinder, Ω , and the physical diminsions of the instrument are known. If the shear stress versus shear rate curve is plotted for a fluid that behaves as Newtonian the results should be a straight line of slope μ, from equation (1.2).

For a general fluid of an unknown shear stress to shear rate behaviour an exact solution of the equations of motion is not possible, although fairly accurate approximations are available for large or small gaps

[11, 50]. If a power-law relationship is assumed between the shear stress and the shear rate the shear rate at the inner cylinder can also be determined from the solution of the equations of motion for a power-law fluid in Couette flow. For this geometry and a power law fluid it can be shown that [50]:

$$\Omega = \frac{n}{2}\sqrt[n]{\frac{\tau_{r\theta}\big|_{r=R_i}}{K}}\left[1 - \frac{R_i}{R_o}^{2/n}\right] \qquad (1.8)$$

Where:

$\tau_{r\theta}$ = shear stress at inner cylinder, [Pa]

K = flow consistency index

n = flow behaviour index

From equation (1.3) we know that at $r = R_i$

$$\tau_{r\theta}\Big|_{r=R_i} = K\left|\frac{-dv_\theta}{dr}\right|^n_{r=R_i} \qquad (1.9)$$

Substituting (1.9) into (1.8) and rearranging

$$\frac{dv_\theta}{dr}\Big|_{r=R_i} = \frac{2\Omega}{n}\frac{1}{\left[1 - \frac{(R_i)}{R_o}^{2/n}\right]} \qquad (1.10)$$

There is a major difficulty in employing equation (1.10), however. That is that the flow behaviour index, n, of the fluid, must be known before the shear rate can be calculated. This is impossible to do because the rheological measurements are being performed to determine

the values of the flow behaviour index and the flow consistency index, K, in order to correlate the measured data with equation (1.3). It should be noted that for n = 1.0 equation (1.10) is equivalent to equation (1.7). Therefore, what was done for the instrument used in this work was to calibrate the output of the shear rate scale which assumed Newtonian fluid behaviour. If the n values calculated from this data are near 1.0 the error in the shear rate can be neglected relative to the stated instrument measurement error of $\pm$ 5%.

The magnitude of the shear rate error in this study was approximated using the geometric dimensions of the viscometer, see Table 1.1, and the minimum value for the flow behaviour index calculated (see Table 2.1). Since this value for n was calculated assuming the Newtonian shear rate relationship equation (1.7), a slightly more conservative value for n of 0.80 was used to estimate the shear rate error.

Using equations (1.7) and (1.10), the geometric dimensions of the instrument, and assuming a minimum flow behaviour index of 0.8 the following results are found:

Newtonian Fluid Assumption

$$\left.\frac{dv_\sigma}{dr}\right|_{r=R_i} = 8.61\ \Omega \qquad (1.11)$$

Power-Law Fluid Assumption, n = 0.80

$$\left.\frac{dv_\sigma}{dr}\right|_{r=R_i} = 8.88\ \Omega \qquad (1.12)$$

Therefore, the maximum error in the shear rate values used in analysing the data in this study was -3.1%. This value was within the stated error limits of the instrument and can therefore be neglected when analysing the data.

Another possible source of measurement error that must be considered when using a Couette viscometer is a shear stress error arising from the assumption of negligible end effects not being satisfied. For this instrument end effects are minimized by the special design of the inner cylinder, see Figure 1.2. The sharp edges and recesses at the top and bottom help reduce the end effects by promoting a more 1-dimensional velocity field in the gap. The recess at the bottom also helps reduce the end effect by trapping an air bubble between the bottom of the cylinder and the fluid being measured. However, even with these precautions taken in the design of the viscometer an end effect correction factor must be applied to the shear stress scale of the output. Based on the physical dimensions of the inner and outer cylinders and applying the German Standard Din 53 018 for end effect corrections, a multiplying factor of 1.13 must be applied to the output shear stress scale.

The final aspect of Couette flow that must be considered for Couette type viscosity measurements was; were the assumptions pertaining to the velocity field satisfied? In other words, was the flow totally laminar or was secondary flow present in the annulus

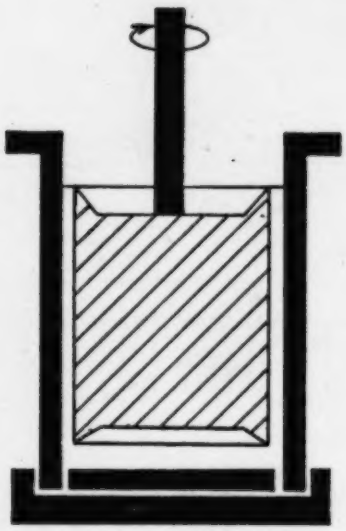

Figure 1.2 Special Design of Viscometer Inner Cylinder

between the two cylinders. From correlations developed by Taylor [43], the criterion that must be satisfied to insure the absense of secondary flow in a Couette viscometer is:

$$\frac{V_i \rho d}{\mu} \left(\frac{d}{R_i}\right)^{1/2} < 41.3 \qquad (1.13)$$

Where:

V_i = peripheral velocity of the inner cylinder

d = width of the gap

R_i = inner radius

ρ = fluid density

μ = absolute fluid viscosity

The assumption in this equation is that the fluid is Newtonian in nature.

In this study the lowest measured viscosity was present in the pure solvent (specifically anthracene oil) at the highest temperature measured (150°C). From the geometric dimensions of the viscometer used and assuming a conservative fluid density of 1.0 g/cm^3 the minimum viscosity required for insurance of laminar flow is found to be $\sim$10 cp by equation 1.13. The minimum apparent viscosity measured in this investigation was $\sim$5 cp.

Therefore secondary flow may have been on the verge of developing in the measurements of anthracene oil viscosity at approximately 150°C. Based on this it can be assumed that the effects of secondary flow would have a negligible effect on the data collected in this work.

An unfortunate consequence of the design of the particular viscometer used in this work was the inability to detect the presence or absense of a stress component normal to the direction of flow. Thus it was impossible to state whether or not a fluid displaying a typically Newtonian shear stress versus shear rate curve (linear) was conclusively a Newtonian fluid. Therefore, in the discussion that follows all viscosities calculated will be stated as "apparent viscosities" whether the shear stress versus shear rate curves are linear or not. Linear shear stress versus shear rate curves will be referred to as "Newtonian behaviour".

1.3 Slurry Viscosity Models - Survey of Theoretical Work

Theoretical work attempting to model the rheological properties of coal slurries, specifically, is non-existant. However, there has been extensive work done, with varying degrees of success, to theoretically describe the flow behaviour of suspensions of spherical particles in Newtonian fluids. The difficulity in deriving theoretical models which accurately account for the rheological behaviour of "real" slurries (eg. coal slurries, ore slurries, etc.) is that there is an almost endless number of parameters that must be accounted for. Some of these parameters are; solids concentration, particle size and size distribution, particle shape, chemical interaction, temperature effects, electrostatic effects, coagulation, etc. The parameters which will be discussed here are those which most affect the behaviour of coal slurries and those which at least to some extent, have been addressed in the literature. These are shear rate, temperature effects, and solids concentration.

1.3.1 Solids Concentration Effect

There has been considerable theoretical work performed in attempting to model the effect of concentration on the viscous properties of suspensions of

rigid particles. One of the several review papers concerning this topic which was quite extensive was by Jeffery and Acrivos (1976) [25]. Most of this work has been an attempt to extend an equation developed by Einstein (1956) which applies to spherical particles which are nearly infinitely diluted in a Newtonian fluid.

$$\mu_{eff} = \mu_o (1 + K\phi) \qquad (1.14)$$

Where:

ϕ = $\frac{\text{Volume of Partices}}{\text{Total Volume of Suspension}}$ $\ll 1$

μ_o = Viscosity of suspending fluid

μ_{eff} = Effective viscosity of suspension

K = 2.5 for very dilute systems.

There exists numerous empirical and theoretical extensions of Einstein's equation in the literature [4,13, 22, 27, 51, 55]. These extensions mainly include higher order terms of, ϕ , but, no matter how complicated these extensions become they do not accurately account for the inevitable non-Newtonian character of the suspension for

$\phi > 0.2$. In fact only Thomas (1963), [48] even considered this problem. Shaheen (1971), [45] presented an empirical correlation for this non-Newtonian behaviour. Recently, [1], however, this problem was addressed theoretically, but experimental work is required to verify the result.

The effects of particle concentration can generally be described as follows:

1. Concentrated suspension ($\phi > 0.2$) are generally shear thinning, except for concentrated suspensions of fine particles which may be dilatant.
2. The degree of non-Newtonian behaviour generally increases with concentration and with decreases in particle size. [28, 54].

1.3.2 Temperature Effect

The temperature dependence of viscosity has been modelled theoretically, with varying degrees of success by Eyring and co-workers [20]. This approximate theory was based on the absolute theory of rate processes. It involves a semi-empirical application of statistical mechanics to the kinetics of flow. Eyring considered a liquid to be an imperfect molecular lattice containing a number of vacant lattice sites called "holes". By considering diffusion and flow as rate processes, based on the motion of the molecules into the available sites or

holes, the following equation was derived for simple Newtonian fluids:

$$\mu = (Nh/V) \exp (\Delta F^*/RT) \qquad (1.15)$$

Where:

μ = viscosity

N = Avogadro's number

h = Plank's constant

V = molar volume

ΔF^* = Standard Free Energy of Activation for Flow per mole

R = Universal gas constant

T = Absolute Temperature

Equation (1.15) was not highly accurate, errors as much as 30 per cent are common. It is stated [6] to be theoretically applicable for hydrocarbons smaller than C_{20}. Therefore for bitumen and anthracene oil it would be expected to fail in the theoretical form as these oils have considerable portions of hydrocarbons larger than C_{20}. However, it indicated an exponential decrease in viscosity with temperature, which agrees with the observed behaviour of many liquids. From the above equation, an empirical correlation can be obtained for viscosity data of many fluids. This is:

$$\mu = A \exp (\Delta H/RT) \qquad (1.16)$$

Where:

ΔH = Activation energy of viscosity (determined experimentally)

A = System constant

R = Universal gas constant

T = Absolute temperature

The above equation is primarily useful for interpolation and extrapolation of viscosity data.

1.4 Survey of Previous Experimental Work

In order to determine if this work was necessary and to determine in what direction this investigation should proceed a review of previous experimental work investigating the rheology of coal-oil slurries was performed.

Prior to 1978 experimental work in attempting to determine the fundamental properties of coal in oil slurries was virtually non-existant. Gradishar et. al. (1943), [36] found good correlation between laboratory tests and pipeline test data for viscosity of coal-oil slurries. The slurry concentrations were below 40 wt% (-100 mesh, -150 μm) and flowing at Reynold's numbers less than 250. The tests were done at room temperature. The effect of varying concentration on viscosity was modelled using the Einstein equation, equation (1.14).

C. Moreland (1963), [36] performed tests using a Brookfield viscometer at various shear rates, various particle size distributions, and at 25°C for coal in mineral oil slurries. For concentrations less than 30 vol % Moreland found that the results were, again, fairly well represented by Einstein's equation, equation (1.14), with K lying between 2.65 and 3.15. Moreland reported pseudoplastic behaviour for concentrations above 10 vol% with the degree of pseudoplastic behaviour increasing with increasing concentration. Moreland also found a definite

dependence of slurry viscosity on slurry particle size distribution.

Since 1978 the amount of work done in coal-oil slurry property measurement increased considerably. This was mainly due to the United States' policy to reduce its dependence on imported oil by making use of other domestic sources of energy, one of these being its large reserves of coal. Therefore, with increasing research and development in coal liquefaction and the firing of boilers with coal and oil mixtures came increased interest in the fundamental properties of coal-oil slurries, one of these being viscosity. Most of this research was done in the United States although work was also performed in Australia, Canada, Great Britian and Japan.

Droege and Chauhan (1978), [13], performed experimental work on the viscous properties of mixtures of pulverized coal with solvent refined coal (SRC). These measurements were performed on Amax and Illinois #6 coal in 30 wt% mixture with their respective SRC's. Two viscometers were used, a falling cylinder type, and a coaxial cylinder type (Haake Rotovisco). Effects of temperature (up to 380°C) and time on viscosity were reported. The mixtures' shear rate behaviour was modelled using a Bingham plastic relationship.

Exxon Research (1978), [16], produced viscosity data on -30 mesh, -500 μm Illinois #6 and Wyodak coal slurried with light and heavy creosote oil. All experiments were

performed at solvent vapour pressure in a coaxial cylinder viscometer. For the Illinois coal a 41 wt% slurry was used. The slurries were reported to be Newtonian. The effect of temperature on viscosity was modelled by the equation:

$$\log \mu = \frac{A}{1.8T-459} + B \qquad (1.17)$$

Where:

μ = slurry viscosity, cp

T = temperature, °K

A,B = system constants

This equation was reported to be applicable up to 200°C. Above 200°C coal swelling affected the viscosity. Viscosities of 22 wt% Illinois coal-oil slurry were reported up to a temperature of 332°C. The slurry was observed to be Newtonian with viscosity decreasing with temperature to 320°C and then showing a sharp rise in viscosity to 332°C due to coal swelling.

Castillo and Williams (1979), [9], performed experiments on slurries of Illincis #6 coal in Araclor 1254 and glycerine. Experiments were performed on various particle size distributions (-230 mesh [62 μm], -230 + 270 mesh [62 to 53 μm], -270 + 400 mesh [53 to 23 μm] and -400 mesh) and coal concentrations of 0, 20, 40, 50, 60 volume %. All of the measurements were made on a cone and plate viscometer (Weissenberg Rheogoniometer R-17) at 20°C. The

slurries are reported Newtonian up to 30 vol% coal concentration. Above 30 vol% coal the slurries were non-Newtonian and all exhibited shear thinning behaviour. The data did not fit any available model for viscosity dependence of dispersions of spherical particles. This shortcoming was explained by concentration effects, aggregation, effects of the fluid medium, and particle size effects.

Munro et. al. (1979), [37], reported experimental work on Northeastern Wyoming subbituminous coal in number 4 fuel oil. Experiments were performed on various particle size distributions (-150 + 170 mesh [104 to 90 μm], -170 +200 mesh [90 to 75 μm], -200 mesh) and coal concentrations of 0, 10, 20, 30, 40, 55 wt %. Measurements were performed in a modified Stromer concentric cylinder viscometer at temperatures of 25, 40, and 60°C. Below 30 wt% coal the slurries were reported to be Newtonian. Above 30 wt% the slurries were observed to be Bingham plastics. No attempt was made to model the temperature or particle size distribution effects. No dependence of slurry viscosity on particle size distribution was observed.

Kreusing, H. and Franke, F.H. (1979), [26], performed tests on coal-fuel oil slurries of 30 to 60 wt% coke, coal and lignite concentrations. The tests were carried out in a rotational viscometer (Haake) over a temperature range of 40 to 90°C. Eight different coal types were tested.

This was done to determine oil savings for coal-oil mixtures versus fuel oil alone. Therefore, no conclusive result of the effect of coal type on slurry properties were reported. However, the general results showed that 40 wt% coke-oil mixtures had the highest viscosity, mineral coal-oil slurry the lowest viscosity and lignite-oil slurry ranged in between the two. This effect was thought to be a function of the porosity of the coals although it was not thouroughly investigated. The effect of temperature on viscosity was reported as an expotential decrease in viscosity with increasing temperature. This effect was not modelled, however. The shear rate - shear stress relationship was not modelled but the mixtures were described as pseudoplastic. The effect of particle size distribution was also analysed. The authors stated that in order to achieve a minimum viscosity at a constant solid matter concentration the particle size distribution should correspond to the maximum packing density of the particles.

S. N. Bhattacharya and L. Barro (1980), [6], performed experimental work on Victorian Brown coal in a coal derived oil. The oil alone had a viscosity of 6.4 cp at 20°C. A close cut of coal particles was used (.085 mm to 0.06 mm, 0.072 mm average) to eliminate particle size as a variable. The viscometer used was a once through capillary tube type. These experiments were performed at atmospheric pressure and over a temperature range of

20-92°C. The coal concentrations considered were 20, 35, and 40 wt%. The 20 and 35 wt% supplies were reported as non-Newtonian with a yield stress below 30°C and Newtonian above 40°C. For a coal concentration of 40 wt% the rheological behaviour was non-Newtonian (shear thinning) with a yield stress over the entire temperature range. A decrease in apparent viscosity with increasing temperature was noted and the rate of change of viscosity decreased with increasing temperature. The rheological properties of the slurries were also observed to change with storage time (viscosity increased during storage).

Y. Yamagata et. al. (1980), [52], reported experimental work carried out with Australian "M" and China "D" coal in heavy fuel oil. Coal concentrations of 20 to 50 wt% were used. The temperature was varied from 20 to 80°C. The results of their work can be summarized with the following equations:

$$\mu_o = a\ D^b\ T^c \quad \text{- (for fuel oil only)} \qquad (1.18)$$

Where:

μ_o = apparent viscosity of fuel oil

D = shear rate

T = temperature

$a\ b\ c$ = constants

and

$$\mu_a = \mu_o .\exp\ (K_2\ Cw/(1-K_1.Cw)$$

Where:

μ_a = apparent slurry viscosity

Cw = concentration by weight of coal

K_1, K_2 = constants which depend on size distribution, particle form and intraction of coal and fuel oil.

The evidence and reasoning for arriving at these models was not clearly stated. Preliminary work on determining the effect of particle size distribution was also done. Capillary and concentric cylinder viscometer data were found to not correlate well.

G.R. Stefurak and B. Ozum (1981), [47, 39], conducted experimental work with subbituminous "Highvale" coal mixed with bitumen and anthracene oil. The coal was crushed to -100 mesh (-150 μm). The coal concentrations examined were 0, 10, 30, and 50 wt%. The shear rate range was 0 to 10 s^{-1}, and the temperature range was 20 to 70°C. The bitumen coal slurries were found to be basically Newtonian. The anthracene oil slurries were reported as pseudoplastic at the higher temperatures and coal

concentrations. The anthracene slurries were modelled using a two parameter power law model with no yield stress. For a constant concentration both K and n were found to decrease with increasing temperature. The temperature dependence of both anthracene and bitumen slurries were modelled using a rate theory equation develped by Eyring, equation (1.16). The data correlated well to this model. Coal concentration effect was discussed but no applicable model was presented.

P.C. Anderson et. al. (1981), [2], reported experimental results for slurries of 40 wt% coal (NCB rank 702) in heavy fuel oil. This work was performed using a coaxial cylinder rotational viscometer (Haake Rotovisco). The shear rate range was 1 to 650 s^{-1} and the temperature range reported was 30 to 90°C. The slurries were non-Newtonian and slightly thixotropic. The shear behaviour of these slurries was modelled using a two parameter power law model with no yeild stress. The slurries were shear thinning with the consistency index typically between 0.8 and 1.0. The temperature effect on viscosity was reported but not modelled. The effect of coal concentration and slurry viscosity was modelled using

$$\eta_{rel} = \left[\frac{1-1.7\ Cv}{0.64}\right]^{-1.6} \qquad (1.20)$$

Where:

η_{rel} = relative viscosity (viscosity of slurry/viscosity of oil)

Cv = volume fraction of coal

Good correlation with the above equation was observed.

J.W. Droege et. al. (1981), [14], performed work to determine the viscosity of coal-oil slurries at conditions typical in a slurry preheater of a coal liquefaction process. The slurry was prepared from -200 mesh, -74 μm, #9 Kentucky coal and Wilsonville SRC recycle solvent in solvent to coal ratios (by weight) of 1.6, 2.0, 2.2, 3.0. The tests were performed over a temperature range of 300 to 650°K under a 14 MPa H_2 atmosphere. For this study Droege developed a coaxial cylinder viscometer with a reciprocating rather than rotating bob. The shear rate range of this instrument was -200 to +200 sec^{-1}. This peculiar viscometer design was developed to try and eliminate settling and to keep the slurry well mixed during the measurements. The viscous behaviour of the slurries was correlated with a Bingham plastic model. Considerable problems were encountered in reproducibility of data due to coal swelling, coking, and solids separation which made these results rather inconclusive. A possible logarithmic decrease in slurry viscosity with increasing temperature was reported.

M.R. Florez (1981), [17], reported the rheological behaviour of process streams in the Exxon Donor solvent

coal liquefaction process. The slurries were prepared from -30 mesh, -500 μm, Illinois and Wyodak coals in their respective hydrotreated recycle solvents. Slurry concentrations of 15, 30, 45 wt% were investigated over a temperature range of 25 to 440°C. These experiments were conducted at solvent vapour pressure in a coaxial cylinder rotational viscometer over a shear rate range of 20 to 2600 sec^{-1}. The 15 wt% slurries were Newtonian up to a shear rate of 2000 sec^{-1}, with some shear thickening behaviour observed at higher shear rates. The 30 and 45 wt% slurries were reported as non-Newtonian, shear thickening. The shear behaviour of these slurries was found to correlate well with a two parameter power law model. A plot of log reduced apparent viscosity ($\mu a = [\mu slurry/\mu solvent]_T$) versus inverse absolute temperature produced parallel linear correlations for all slurry concentrations.

Another project aimed at producing viscosity data at liquefaction process conditions was conducted at Oakridge National Research Laboratories by Lee, Oswald, Hightower, Youngblood, et.al., [27, 29-33]. These investigators have been developing a pipeline (capillary tube) viscometer system since 1978. Initial tests with -170 mesh, -85 μm Illinois #6 coal in Wilsonville recycle solvent (35 wt% coal) showed that slurry behaved as a power law fluid (shear thinning). The temperature range investigated was 400 to 700 K at (14 MPa) and the shear rate range was 100

to 600 sec^{-1}. A viscosity peak was observed at the gelation temperature of 572 K to 644 K. Below 400 K the slurry was described as Newtonian. In 1980/81, in preparation for the SRC-1 demonstration plant run work was carried out with Kentucky #9 coal, -170 mesh, -85 μm, and Wilsonville recycle solvent (35 wt% coal slurry). Data for these runs correlated equally well with a power law model and a Bingham plastic model.

General references [21,28,52] suggested that coal-oil slurries should behave as pseudoplastic fluids with no yield stress for coal concentrations above approximately 30 vol %. For lower concentrations the suspension should display the rheological behaviour typical of the suspending fluid. However as can be seen from the review presented above these generalities are not universally supplied by the experimental work.

Viscosity-temperature dependence generalizations for coal slurries were not available in the literature. However, from the experimental work where temperature effects were investigated and correlated an exponential or power type dependence of viscosity on temperature was suggested.

From previous work, then, it can be seen that general quantitative description of the effects of shear rate, temperature and coal concentration were not available. The large variation in previous experimental results was most likely due to the fact that the number of factors

that can affect slurry viscosity is very large (ie. solvent properties, coal type, coal particle size distribution, coal particle shape, chemical interactions, etc). With this in mind, it seems necessary to determine the viscosity data and behaviour for each particular slurry as it is required.

1.5 Experimental Apparatus and Procedure

This work investigated the flow behaviour of coal-anthracene oil and coal-bitumen slurries. The parameters which were varied, so that their effects on slurry viscosity could be determined, were the shear rate the temperature, and the coal concentration. The instrument used to measure the slurry viscosity was a Haake Rotovisco concentric cylinder viscometer. This unit was comprised of various components; an M-150 sensor head, a TP-24 electric heater-temperature controller, an MV-400-II cup and bob combination, and an RV-100 programmable controller-plotter. Details of the dimensions and capabilities of this equipment are shown in Table 1.1.

Table 1.1 Haake Viscometer - Physical Data

Measuring Drive Unit:	Maximum Torque = 1.47 N-cm
	Maximum Speed = 500 rpm
Measuring System:	Rotor Radius = 18.4 mm
	Rotor Length = 60.0 mm
	Stator (cup) Radius = 21.0 mm
	Sample Volume = 55 cm^3
Heater:	Temperature Range: Ambient to 400°C
	Control Variation: $\pm$ 0.1°C

The viscometer was designed so that the shear rate could be varied from zero to a user specified value and back to zero again in a specified time period. This feature facilitated easy recognition of rheopectic or thixotropic behavior in the sample being tested. This feature also made possible the generation of a flow curve (shear stress versus shear rate) on the plotter in one experiment rather than many, as is usually the case with other instruments. The time period selected to cycle from zero shear rate to the full scale shear rate and back to zero shear rate was eight minutes for all experiments. This time was used because it would make unsteady flow effects as well as viscous heating effects negligible. The linear scales of the plotter output were converted directly to shear stress (Y-axis), in Pa, and shear rate (X-axis), in s^{-1} using numerical multiplication factors given for the particular cup and bob combination used. In this study the shear stress scale factor was 1.13, and the shear rate scale factor was 4.50. Only one cup and bob combination was used throughout the work. Figure 1.3 shows a typical viscometer plotter output.

The slurries used in this study were prepared containing 0, 10, 30, and 50 weight percent coal using anthracene oil and bitumen as solvents. The coal used was an Alberta subbituminous, "Highvale" coal acquired from a strip mine near Wabamun Alberta. The coal was pulverized to less than 150 micron maximum particle size and oven

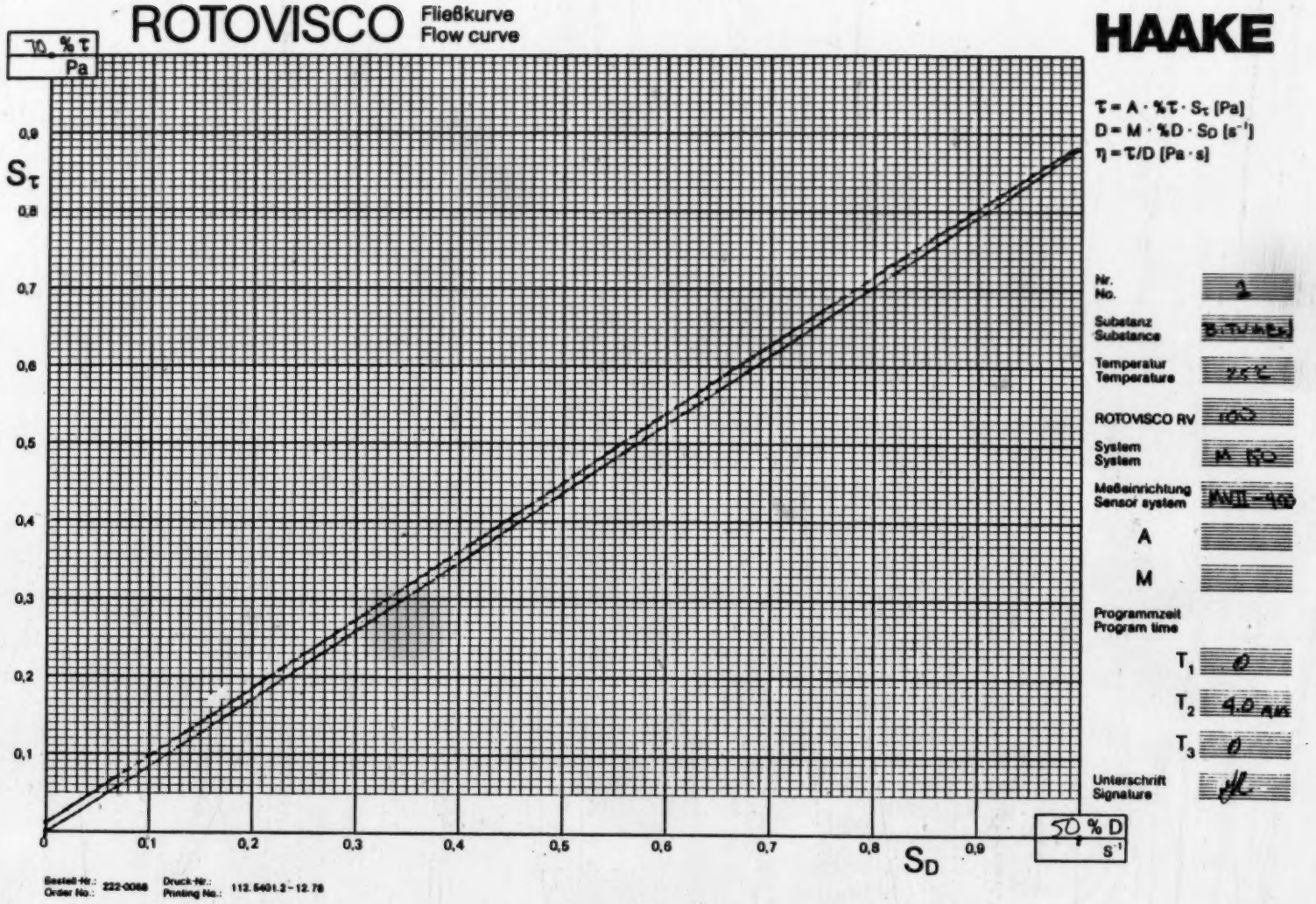

Figure 1.3 Typical Haake Viscometer Output

dried at 70°C under vacuum prior to the slurry preparation. The bitumen was Suncor coker feed bitumen obtained from the Suncor Oilsands plant near Fort McMurray, Alberta. The anthrancene oil, a by-product of coking coal for the steel industry, was obtained from Stelco in Hamilton, Ontario. Laboratory analyses of the coal and the two solvents are provided in Table 1.2. The particle size distribution of the coal used is given in Appendix A. A summary of the experiment variables investigated is given in Table 1.3.

The procedure for this investigation was to introduce the slurry into the cup of the viscometer, mix it well, and then measure the temperature of the fluid using a thermocouple placed into the fluid. If the temperature was stable, the thermocouple was removed and a flow curve was then generated. After the measurement was complete the slurry temperature was checked to see if it had changed. If the temperature differed from the initial measured value by more than 0.2°C the run was repeated. This value of 0.2°C was chosen because the heater had a published temperature control capability of $\pm$0.1°C. After a successful run the temperature setting of the heater was then increased by 15°C and the preceding steps were repeated. When the final temperature of 150°C was reached the sample was cooled and measurements were taken at approximately 25°C temperature intervals until ambient conditions were again reached. When all the viscosity

Table 1.2 LABORATORY ANALYSIS OF COAL, ANTHRACENE OIL AND BITUMEN

Coal: Highvale Subbituminous, Pulverized to -150 μm, dried

	%
Moisture	8.86
Ash	10.72
Volatile Matter	31.83
Fixed Carbon	48.59

Anthracene Oil:

	%
Asphaltenes	3.36
Resins	14.2
Oils	82.2
Elemental Analysis (92.1% C, 5.35% H, 0.55% N, 0.96% S, 1.13% O)	

Bitumen:

	%
Water	< 0.5
Ash	0.5 - 1.0
Residual naphtha	< 3.0
Asphaltenes	13.1 - 15.5
Elemental Analysis (82.6% C, 10.6% H, 0.8% N, 3.7% S, 1.6% O)	

Table 1.3 EXPERIMENTAL VARIABLES

Coal:	Alberta Subbituminous (Highvale) - 150 micron
Coal Concentration:	0, 10, 30, 50% by weight
Solvents:	1) Anthracene Oil 2) Bitumen
Temperature Range:	25° to 150°C
Shear Rate Range:	Variable 0 to 1170 s^{-1} Max.

measurements for a particular slurry were complete the instrument was cleaned and the calibration was checked using viscosity standards of 10, 1.0 and 0.1 Pa-s absolute viscosity at 25°C. After the calibration check, the above procedure was repeated for the next slurry. Since there was no cooling capability on the heater, and, therefore, temperature control was determined by natural convection to the surrounding air, no attempt was made to exactly duplicate the temperatures at which the viscosity measurements were taken for each particular slurry. The repeatability of the experiments was checked by repeating a viscosity measurement of each particular slurry at a temperature where the viscosity had been measured previously.

2.0 RESULTS AND DISCUSSION

This section reports and discusses the effects of shear rate, temperature, and coal concentration on the apparent viscosities of the two coal-oil slurries investigated.

2.1 Coal-Anthracene Oil Slurries

2.1.1. Shear Rate Behaviour

Anthracene oil and coal-anthracene oil slurries were subjected, depending on temperature and coal concentration to shear rates ranging from 0 to 1170 s^{-1}. Anthracene oil alone was slightly shear thinning (psuedoplastic) at low temperatures (25-40°C). As the temperature was increased, however, the behaviour changed gradually to a slight shear thickening (dilatant) nature at high temperatures (140-150°C). The transition in the observed flow behaviour from pseudoplastic to dilatant occurred at a temperature in the range of 45 to 60°C. This temperature range also corresponds to that at which a change was observed in physical composition and consistency of anthracene oil. Below approximately 60°C anthracene oil had a somewhat waxy crystalline structure. This would possibly provide an explanation for the slight shear thinning behaviour of the oil at low temperatures. As the crystalline structure was broken down by the shearing of the fluid between the cylinders of the viscometer the

relative resistance to flow of the oil would be expected to decrease somewhat. At the higher temperatures, where the crystalline structure had been destroyed, anthracene oil became a slightly dilatant fluid.

When coal was added to the anthracene oil the shear thickening behaviour at higher temperatures was suppressed. As the coal concentration was increased the slurries tended to become slightly psuedoplastic in nature. Below coal concentration of 50 wt% however, the deviation from Newtonian behaviour was not large enough to warrant the use of a non-Newtonian shear stress - shear rate model. Typically the least squares linear curve fit the shear stress versus shear rate data did not have a correlation coefficient less than 0.99. Figures 2.1, 2.2 and 2.3 show typical shear stress versus shear rate plots for 0, 10 and 30 wt% coal-anthracene oil slurries, respectively, at temperatures near 50°C. As can be seen the deviation from linearity (Newtonian behaviour) was negligible. Shear stress versus shear rate data is included in Appendix C.

The 50 wt% coal-anthracene oil slurry was significantly pseudoplastic in nature over the entire temperature range investigated. Figure 2.4 shows a typical shear stress versus shear rate plot for the 50 wt% coal-anthracene oil slurry near 50°C. It can be seen from this plot that the deviation from Newtonian behaviour is significant. For the 50 wt% coal-anthracene slurry

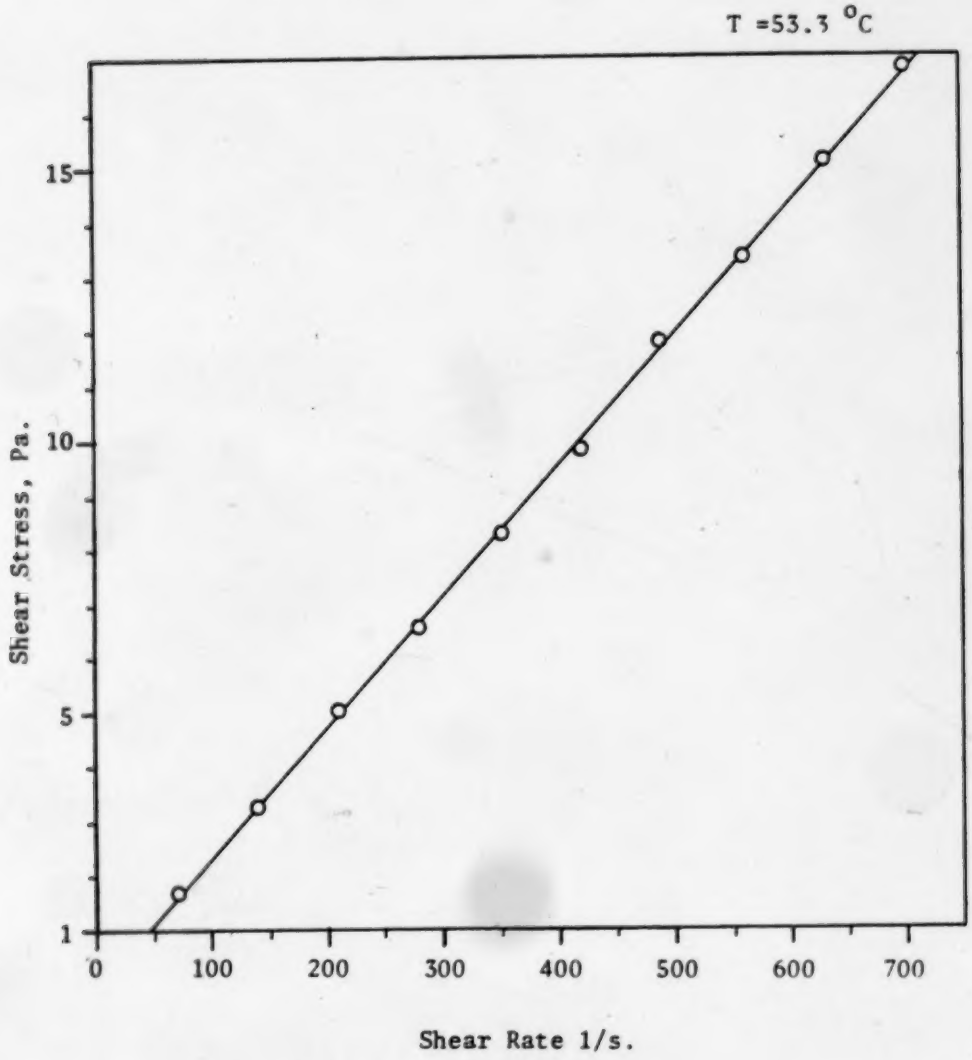

Figure 2.1 Shear Stress versus Shear Rate Plot
Anthracene Oil

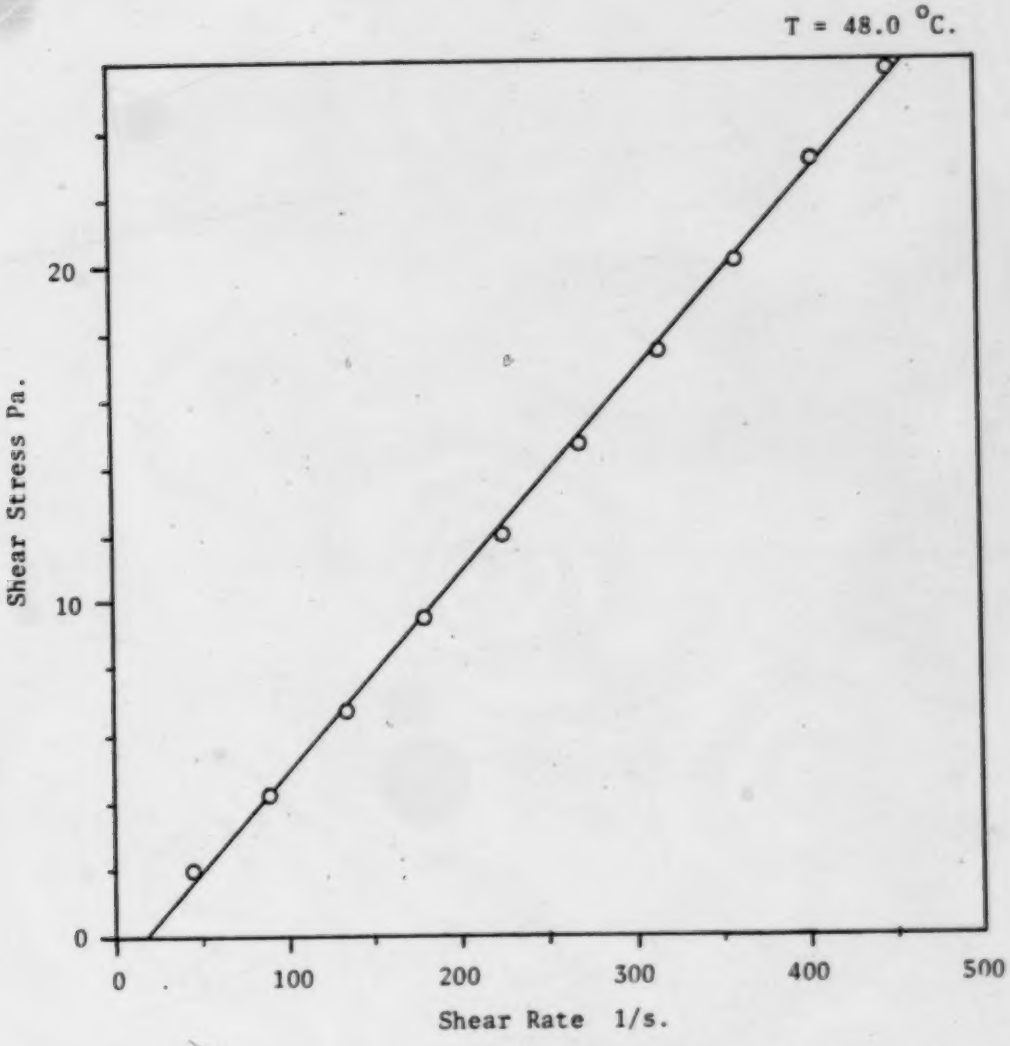

Figure 2.2 Shear Stress versus Shear Rate Plot
10 wt% Coal-Anthracene Oil Slurry

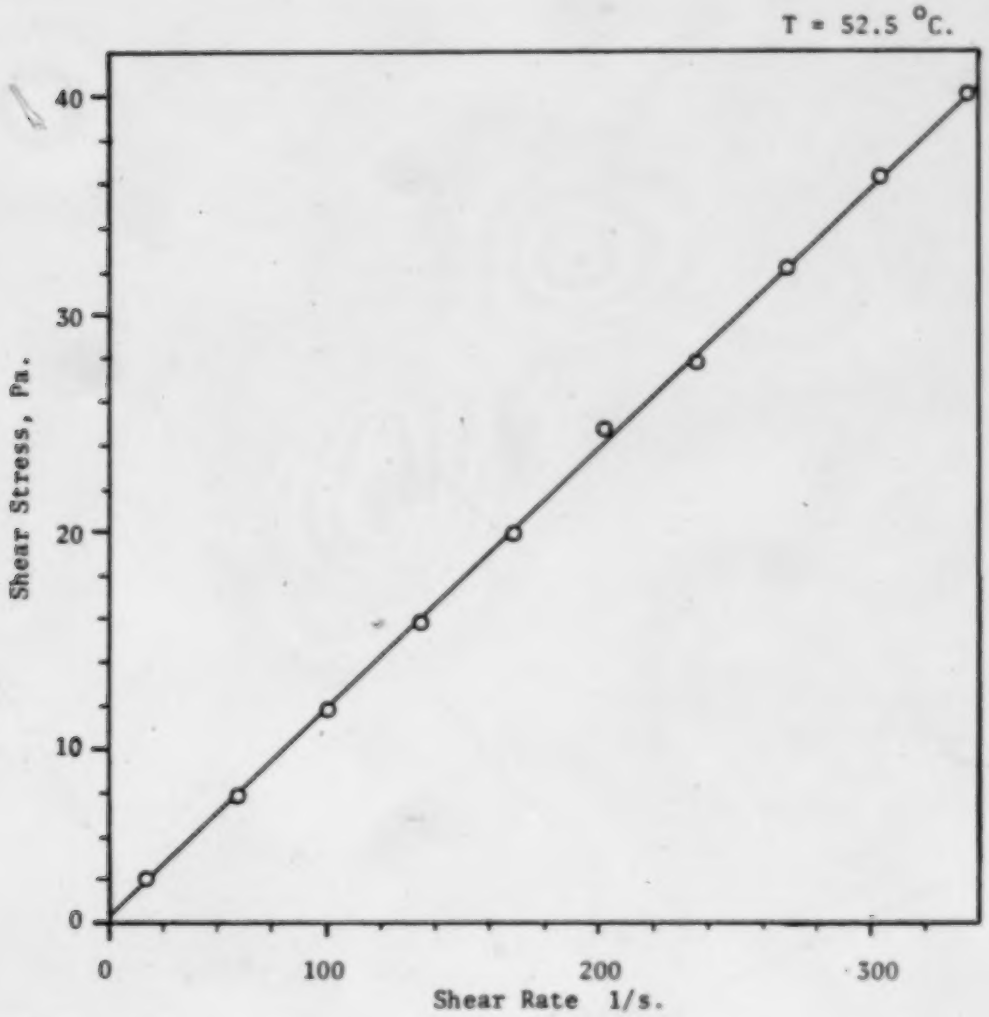

Figure 2.3 Shear Stress versus Shear Rate Plot
30% wt% Coal-Anthracene Oil Slurry

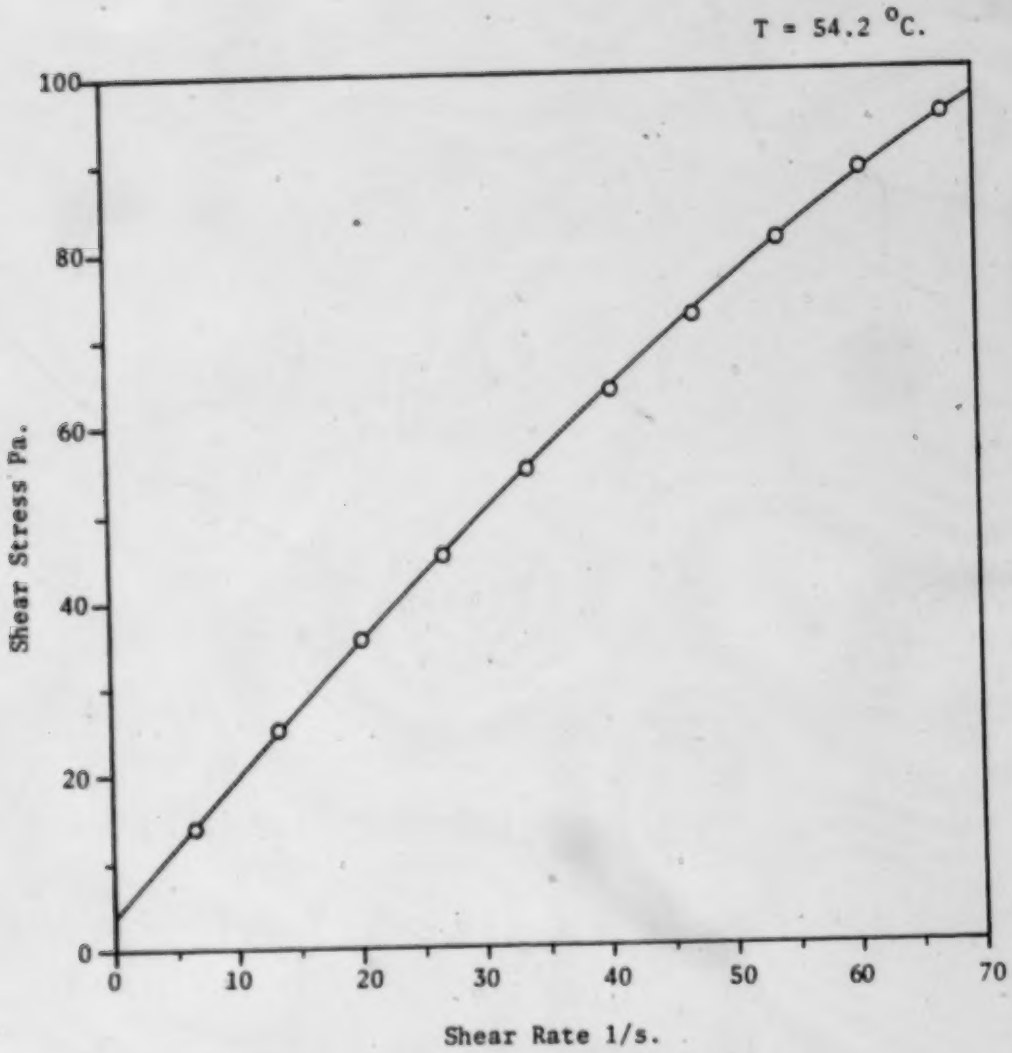

Figure 2.4 Shear Stress versus Shear Rate Plot
50 wt% Coal-Anthracene Oil Slurry

the two parameter power law model, equation (1.3), was used to correlate the data. Table 2.1 presents the results of this correlation for several temperatures. The flow consistency index, K, and the flow behaviour index, n, values in Table 2.1 were calculated from a linear least squares fit to the log (shear stress) versus log (shear rate) data. The slope of this data being n, the intercept being Log (K). The correlation coefficient, r^2, in Table 2.1 indicates the linearity of such a fit. As can be seen the power law model fit the data for the 50 wt% coal-anthracene oil slurry for the 50 wt% coal-anthracene oil slurry very well.

The pseudoplastic behaviour of the high concentration coal-anthracene oil slurry could at least, partially be due to the irregular shape of the coal particles. When shearing was applied to the slurry these particles would tend to align themselves with the flow. This alignment of the particles, as the shear rate increased, would tend to reduce the relative resistance to flow generated by the system.

Trends that should be noted in the data presented in Table 2.1 are that the flow consistency index, K, decreased considerably with increased temperature and the flow behaviour index, n, tends to increase slightly with increased temperature. This result was different than previous experimental work [47] which reported decreasing

Table 2.1 POWER LAW PARAMETERS - K AND n - 50 WT% COAL-ANTHRACENE OIL SLURRY

Temperature (K)	K (Pa-s)	n	Correlation (r^2)
317.7	10.6739	0.8326	0.9997
327.4	2.9023	0.8329	0.9998
357.5	0.4430	0.8757	0.9989
396.4	0.1427	0.8888	0.9974
418.0	0.0672	0.9180	0.9998

K and n values with increasing temperature [39].

2.1.2. Temperature Behaviour

Viscosity data for Anthracene oil and anthracene oil-coal slurries were collected over a temperature range of ∿25 to 150°C in both heating and cooling. The data was then correlated using equation (1.6), had this model been valid for the coal-anthracene oil slurries a semi-logarithmic plot of apparent viscosity versus inverse absolute temperature should be produced linear curves of slope $\Delta H/R$, as described in section 1. . As can be seen from Figures 2.5 and 2.6 which depict the coal-anthracene oil slurry apparent viscosity variation with temperature in heating and cooling respectively the curves were not particularily linear. The non-linearity of the heating data Figure 2.5, could, in part, be due to evaporation of part of the liquid sample during the heat up phase of the experiments. The cooling data, Figure 2.6, produced more linear curves than the heating data. A linear least squares fit was performed on the cooling data and the results of this fit is shown in Table 2.2. The data correlated fairly well with a linear fit (r^2min=0.8499). The notable feature of the results in Table 2.2 is that the activation energy of flow, ΔH, remains nearly constant for all of the coal concentrations with the exception of the 50 wt% slurry. This would indicate that ΔH is

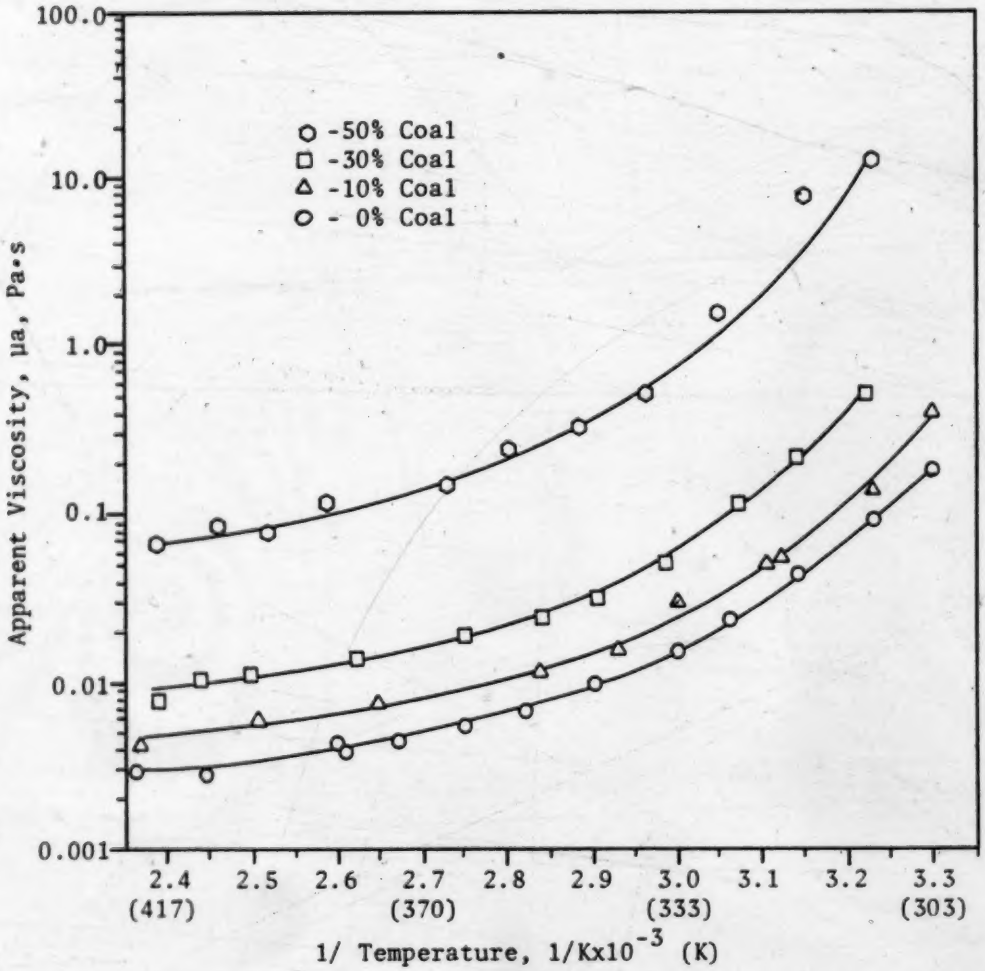

Figure 2.5 Coal-Anthracene Oil Slurry Apparent Viscosity versus Inverse Temperature Plot - Heating

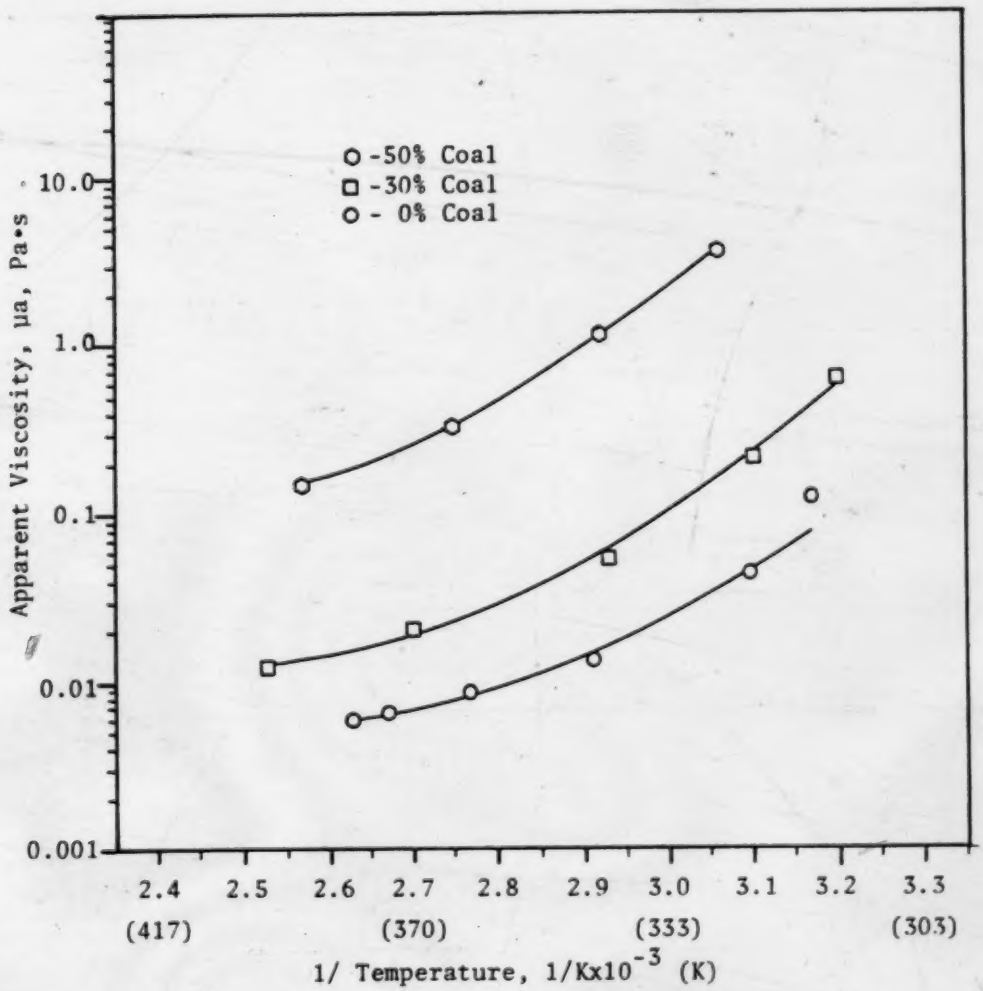

Figure 2.6 Coal-Anthracene Oil Slurry Apparent Viscosity versus Inverse Temperature Plot - Cooling

Table 2.2 COAL-ANTHRACENE OIL SLURRY ACTIVATION ENERGY OF FLOW

Coal Conc. (wt%)	H (kJ/kg mole-K)	Correlation (r^2)
0	8.789	0.9222
10	8.932	0.8499
30	8.272	0.9733
50	10.08	0.9715

relatively insensitive to solids concentration and is determined by the suspending fluid. This result was reported in previous experimental work [39].

The non-linearity of the curves in Figure 2.6 was possible due to the complex physical nature of the anthracene oil, as was previously noted. It should be noted, however, that the instantaneous slope of all the curves in Figure 2.5 and 2.6 are nearly equivalent. This would indicate that the activation energy of flow for the anthracene oil slurries may be temperature dependent but was still relatively insensitive to changes in coal concentration.

2.2 Coal-Bitumen Slurries

2.2.1 Shear Rate Behaviour

Bitumen and coal-bitumen slurries were subjected to the same test conditions as the anthracene oil slurries (Section 2.1.1). The results obtained for the bitumen slurries were generally comparable to those of the anthracene oil slurries. Bitumen, without coal added, behaved almost perfectly Newtonian. Unlike the anthracene oil, bitumen was a physically homogeneous liquid throughout the temperature range investigated. With the addition of coal to the bitumen a slightly pseudoplastic character was observed. This behaviour was also previously observed in the anthracene oil slurries; (Section 2.1.1). For the bitumen slurries, as with anthracene oil slurries, the deviation from Newtonian behaviour was not significant until a coal concentration of 50 wt% was reached. At 50 wt% coal concentration the bitumen slurries exhibited a definite pseudoplastic character. Figures 2.7, 2.8 and 2.9 illustrate the typically Newtonian behaviour of the 0, 10 and 30 wt% coal-bitumen slurries, respectively. Figure 2.10 depicts the definite pseudoplastic nature of the 50 wt% coal-bitumen slurry.

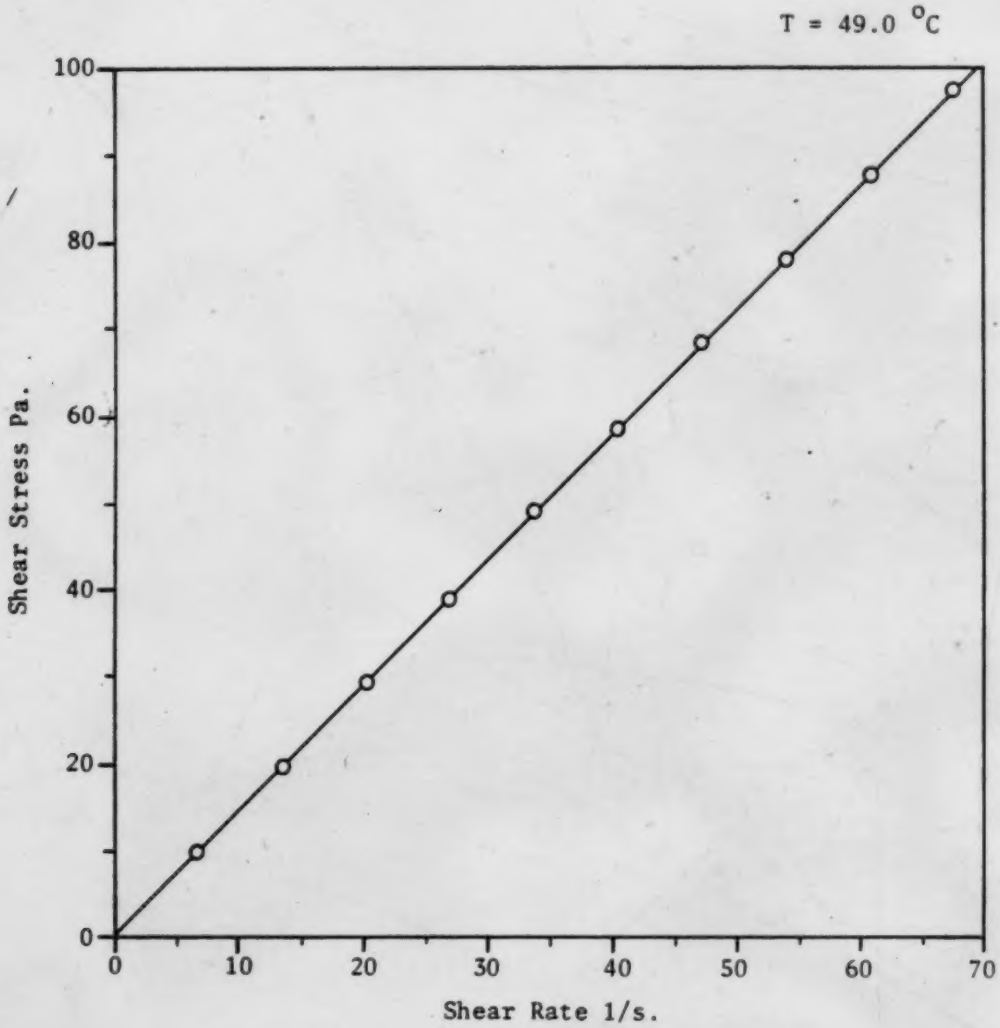

Figure 2.7 Shear Stress versus Shear Rate Plot
Bitumen

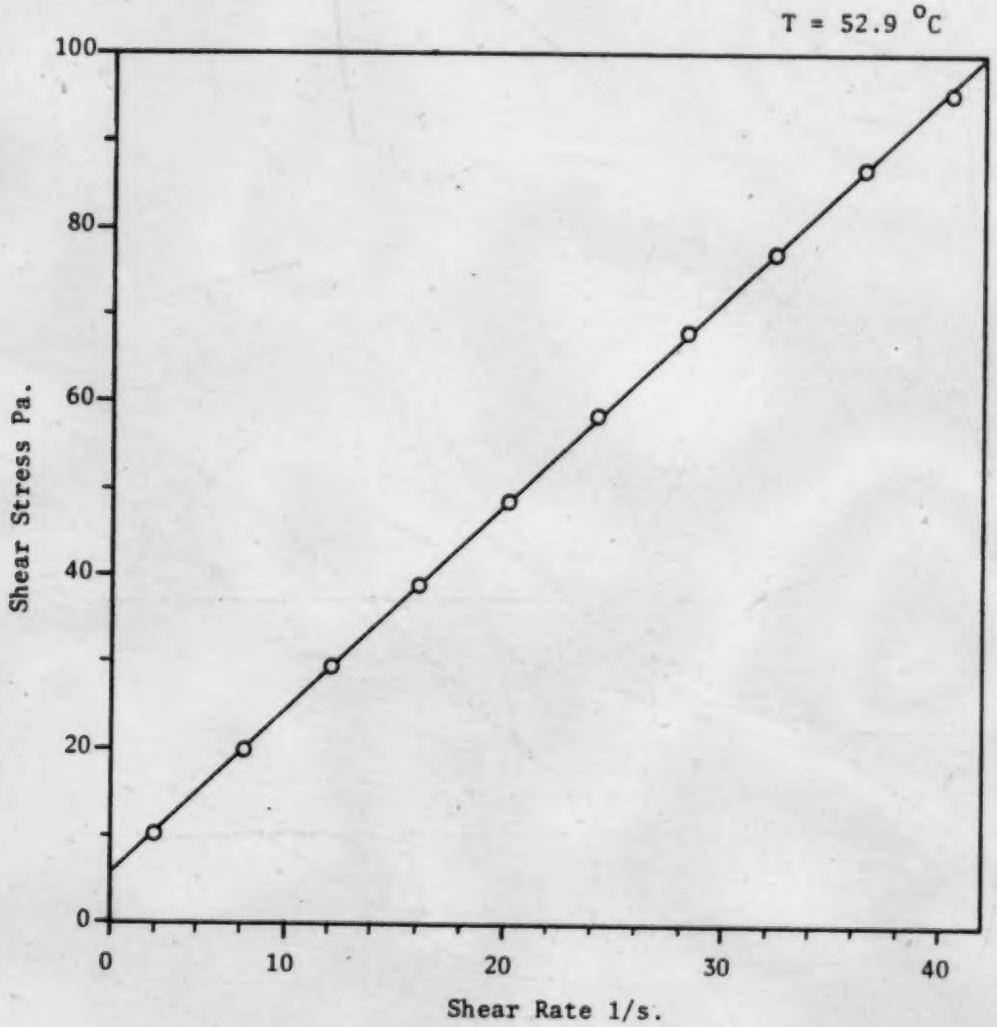

Figure 2.8 Shear Stress versus Shear Rate Plot
10 wt% Coal-Bitumen Slurry

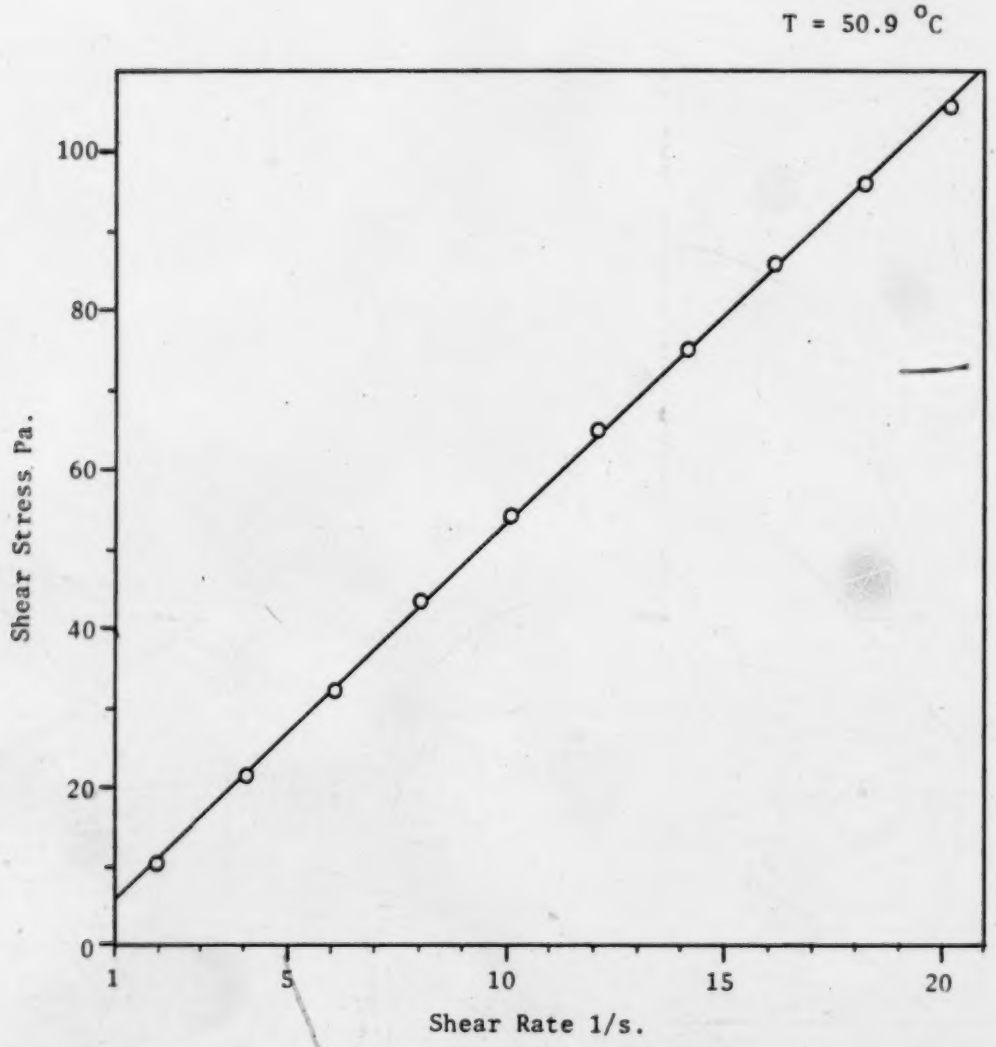

Figure 2.9 Shear Stress versus Shear Rate Plot
30 wt% Coal-Bitumen Slurry

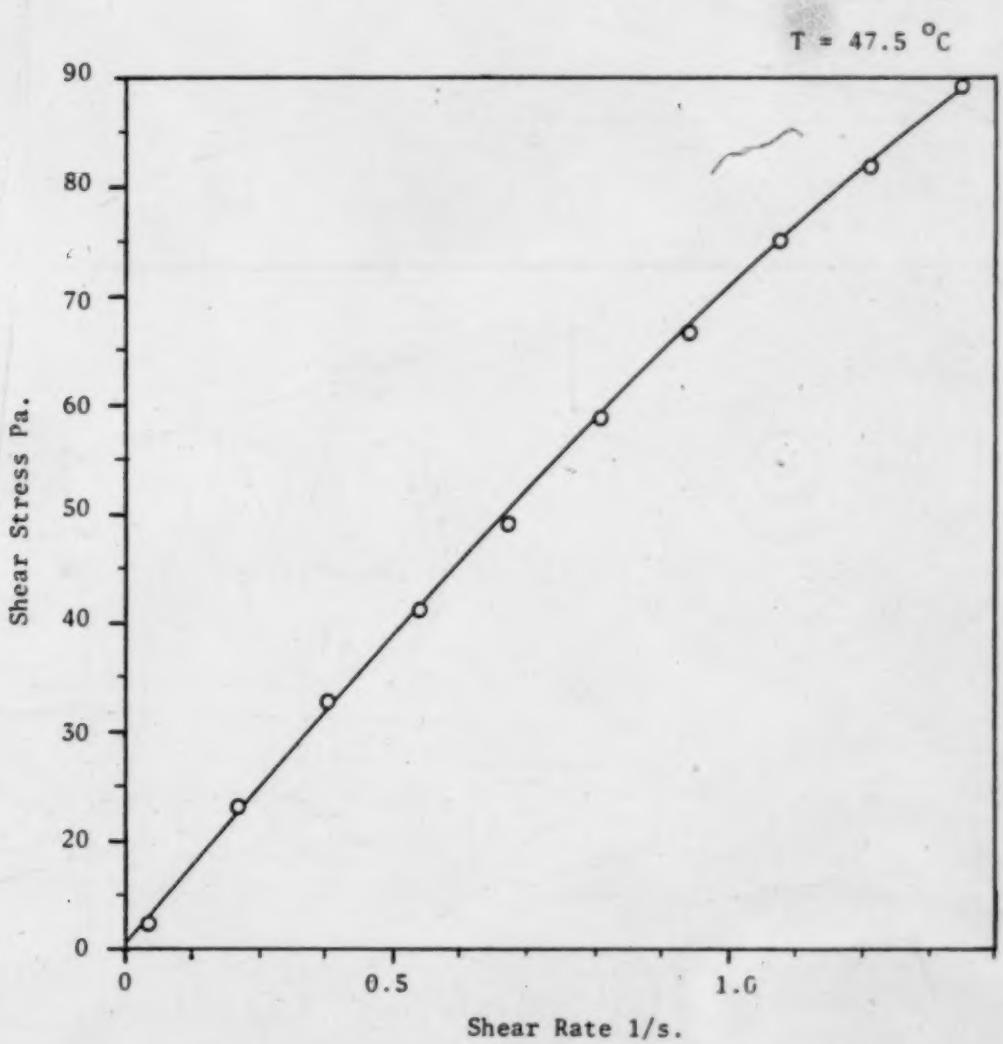

Figure 2.10 Shear Stress versus Shear Rate Plot
50 wt% Coal-Bitumen Slurry

The 50% coal-bitumen data was also correlated using a two parameter power law model, equation (1.3). The results of this correlation are given in Table 2.3.

As was the case for the coal-anthracene oil slurries the flow consistency index, K, exhibited a large decrease with increasing temperature while the flow behaviour index, n, showed a slight increase with increasing temperature. The power law model fit the data exceptionally well as is reflected by the values of the correlation coefficients, r^2, which were all very near to a value of 1.0.

2.2.2 Temperature Behaviour

The variation with temperature of the apparent viscosities of coal-bitumen slurries was also fit with the model equation (1.16). Figures 2.11 and 2.12 show the semi-logarithmic plots of apparent viscosity versus inverse absolute temperature for coal-bitumen slurries during heating and cooling, respectively. The result was a significantly better agreement with the model equation than was observed for the coal-anthracene oil slurries. The cooling data shows exceptionally good agreement. A least squares fit of the cooling data was performed and the results of this are given in table 2.4. In this case the linearity of the data was excellent, as compared with the coal-anthracene oil slurries (Table 2.2). The

Table 2.3 POWER LAW PARAMETERS - K AND n - 50 WT% COAL-BITUMEN SLURRY

Temperature (K)	K (Pa-s)	n	Correlation (r^2)
320.7	69.8062	0.8537	0.9997
327.2	32.3105	0.8244	0.9929
360.8	6.1178	0.8917	0.9997
401.2	1.4654	0.9188	0.9998
420.2	0.9641	0.9136	1.0000

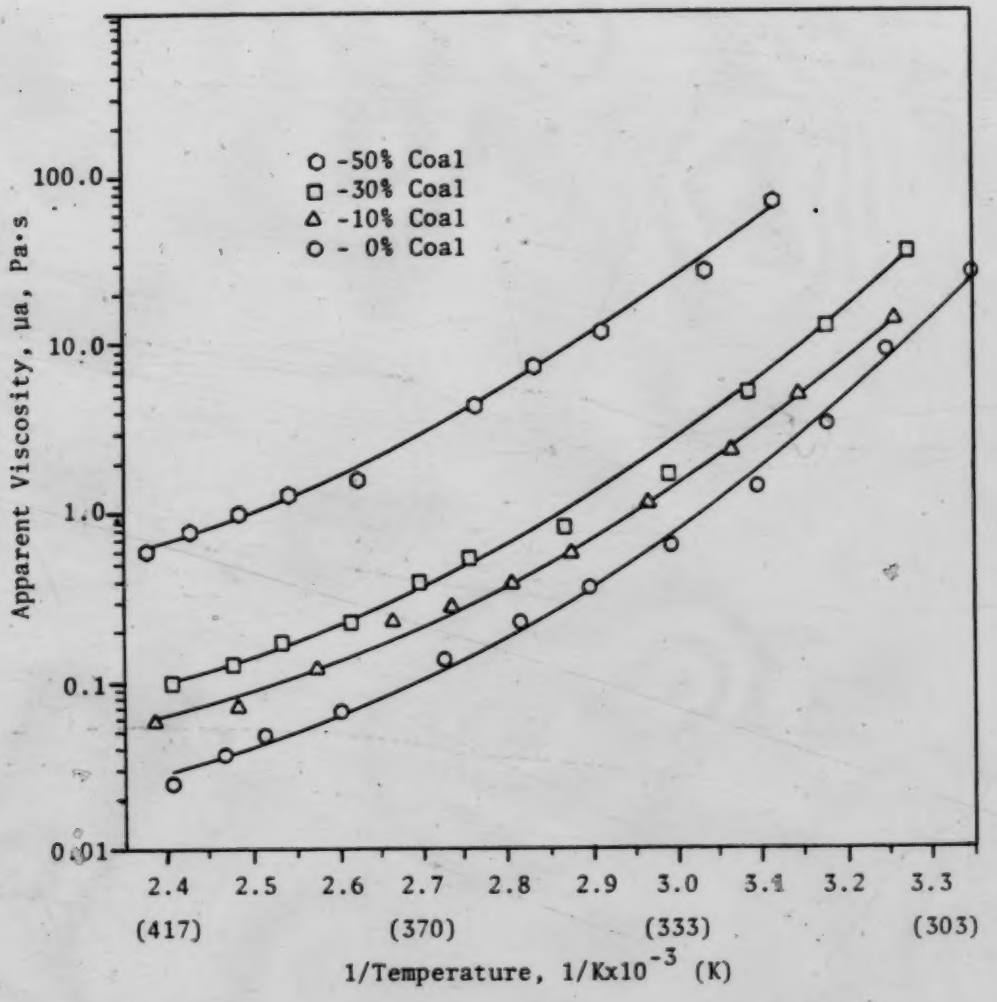

Figure 2.11 Coal-Bitumen Slurry - Apparent Viscosity versus Inverse Temperature Plot - Heating

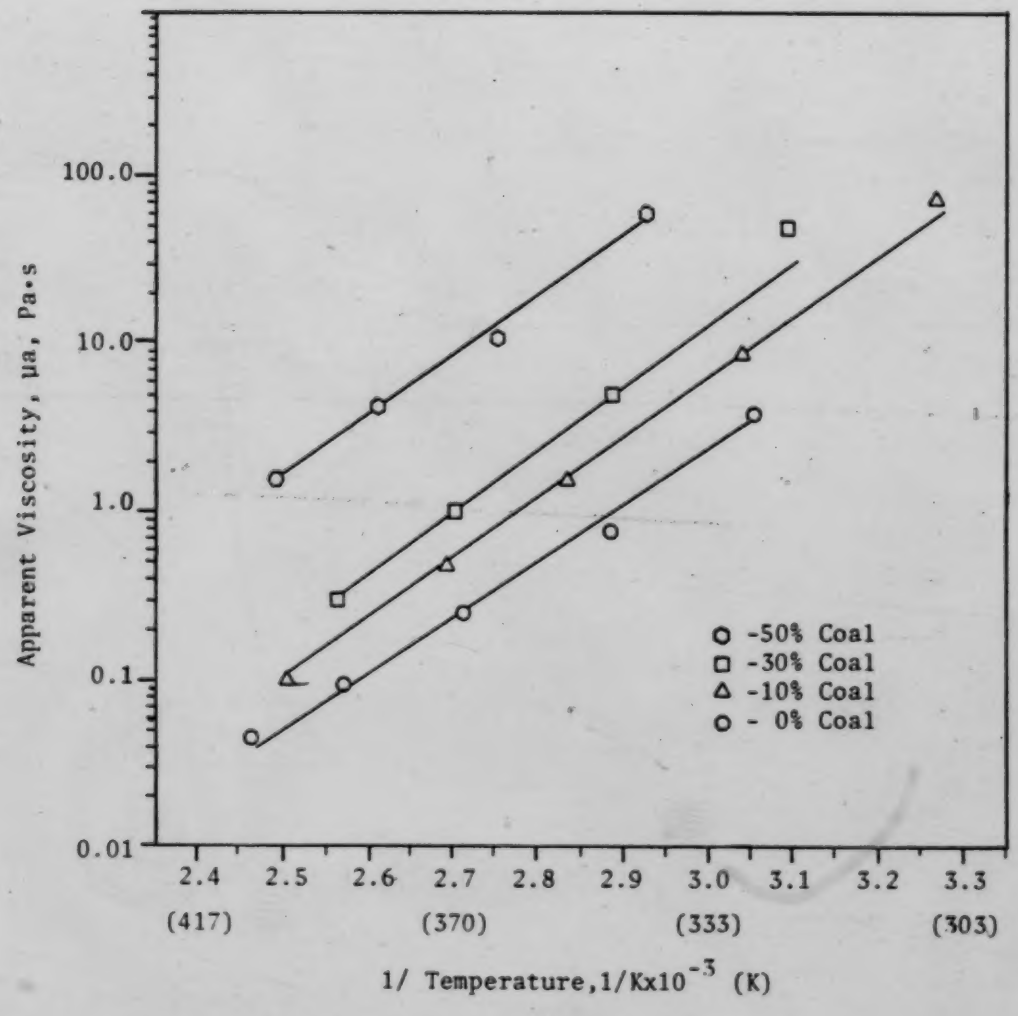

Figure 2.12 Coal-Bitumen Slurry
Apparent Viscosity versus Inverse
Temperature Plot - Cooling

Table 2.4 COAL-BITUMEN SLURRY ACTIVATION ENERGY OF FLOW

Coal Conc. (wt%)	H (kJ/kg mole-K)	Correlation (r^2)
0	11.79	0.9945
10	13.58	0.9992
30	15.01	0.9967
50	12.89	0.9843

activation energy of flow, ΔH, however, was not as consistent in value as was the case with anthracene oil. A dependence of ΔH on coal concentration is not apparent, however. The scatter observed in the data may have been due to the limited number of experiments conducted during cooling. Therefore, it would be reasonable to conclude that the activation energy of flow for the coal-bitumen slurries was a constant value in the range of 12 to 15 kJ/kg-mole-°K and was independent of coal concentration, (i.e.) it was a property of the bitumen alone. This result was consistent with previous experimental work [39].

The non-linearity of the heating curves, Figure 2.11, was most likely due to the significant evaporation of bitumen which was observed during the course of the experiments. Thermo Gravimetric Analysis (TGA) were conducted on bitumen and coal-bitumen slurries in order to attempt to quantify the evaporation of the bitumen solvent during the measurements. These TGA curves are included in Appendix B. Generally the amount of bitumen evaporation was $\sim$10% by weight of the sample. As the temperature increased from $\sim$25 to 150°C the lighter hydrocarbons in the bitumen evaporated. Therefore the apparent viscosity of the material would be expected to increase. The increase in apparent viscosity would explain the concave curves shown in Figure 2.11.

2.3 Coal Concentration Effect

The effect of coal concentration on apparent slurry viscosity was investigated over a range of 0 to 50% by weight coal. The reduced slurry viscosity (μ_a slurry/ μ_a solvent, calculated at a common temperature) and the volume concentration of coal were calculated and the results are plotted in Figures 2.13 and 2.14 for temperatures of approximately 50°C and 120°C respectively. The volume concentration of coal was calculated knowing the weight percent concentration and the density of the coal and the two solvents, (ρ coal=1.6 g/cm^3; ρ_{bit}=0.97 g/cm^3; ρ_{anth}=1.1 g/cm^3). The results shown in Figures 2.13 and 2.14 indicate that the reduced viscosities increased in a fairly linear manner up to about 24% by volume (30 wt%) coal concentration. Above this concentration there was a drastic increase in the reduced viscosity. It also seemed that the reduced viscosity versus volume concentration data produced basically the same result independent of which oil was used to make the slurries.

The linear portions of Figures 2.13 and 2.14 (ϕ<25%) were correlated with the Einstein model equation (1.14). The slope of the line through the data is the constant, K, in equation (1.14). The results of this correlation are given in Table 2.5. With the exception of the bitumen slurry at 50°C in the cooling mode, the values for K all

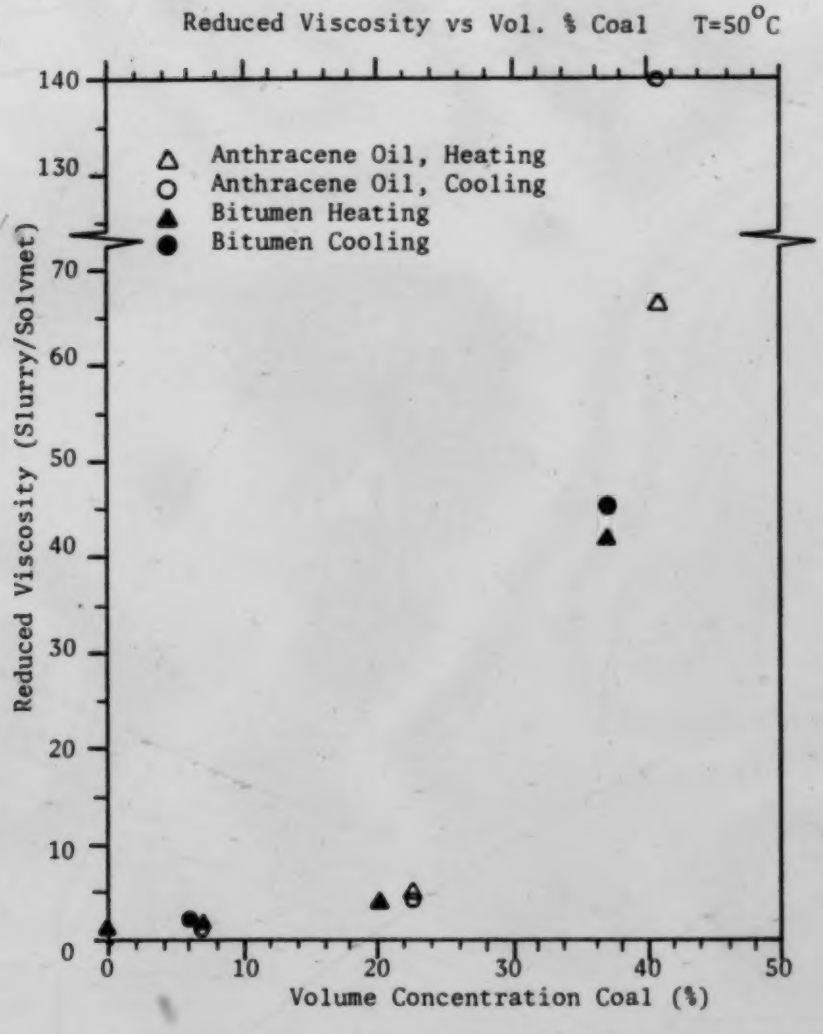

Figure 2.13 Reduced Viscosity versus Coal Concentration Plot- Low Temperature

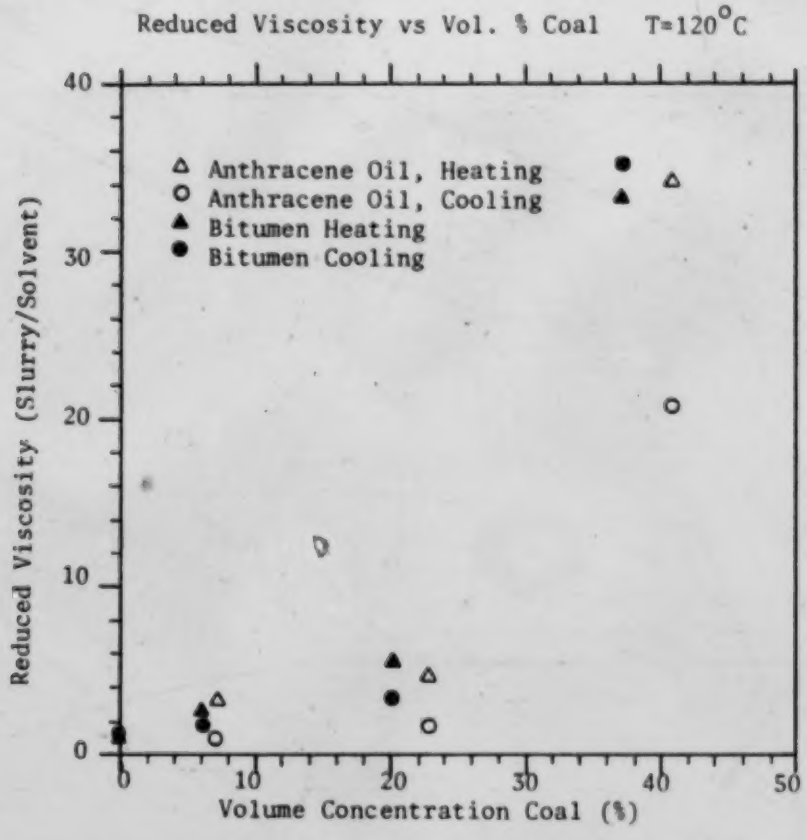

Figure 2.14 Reduced Viscosity versus Coal Concentration Plot- High Temperature

Table 2.5 VALUES OF K FOR REDUCED VISCOSITY VERSUS COAL CONCENTRATION DATA - (<25%)

K - VALUES

Oil	Heating		Cooling	
	T = 50°C	T = 120°C	T = 50°C	T = 120°C
Anthracene	16.3	11.8	15.4	10.3
Bitumen	15.0	15.3	26.8	12.5

fell in a fairly close range between 10.0 and 16.0, irrespective of the solvent used. These values for K are high as compared with others reported [19]. Equation (1.14) was derived for non-interacting, uniform spherical particles. The large values for K found in this work may have been due to the irregular shape of the coal particles. Chemical interactions between the particles and between the particles and the fluid may also have contributed to the large values for K.

In Figures 2.13 and 2.14, for coal concentrations above 30% by volume, the reduced viscosity of the slurries increased with an almost infinite rate. This behaviour was most probably due to increased energy dissipation from coal particle collisions as compared to mainly fluid shearing at lower coal concentrations. This effect was observed in previous work [39, 47].

Finally, the apparent viscosities of the slurries studied in this work were compared with the reported viscosities of other common fluids. This was done in order to acquire a better practical "feel" for the numbers that were dealt with in this study. The results of this comparison are shown in Figure 2.15 where the apparent viscosity versus temperature is plotted for bitumen, anthracene oil, 30 wt% coal-bitumen and 50 wt% coal-anthracene oil slurries. This figure showed that the apparent viscosities of the slurries studied here were at the high end of the viscosity scale, as compared with crude and fuel oils.

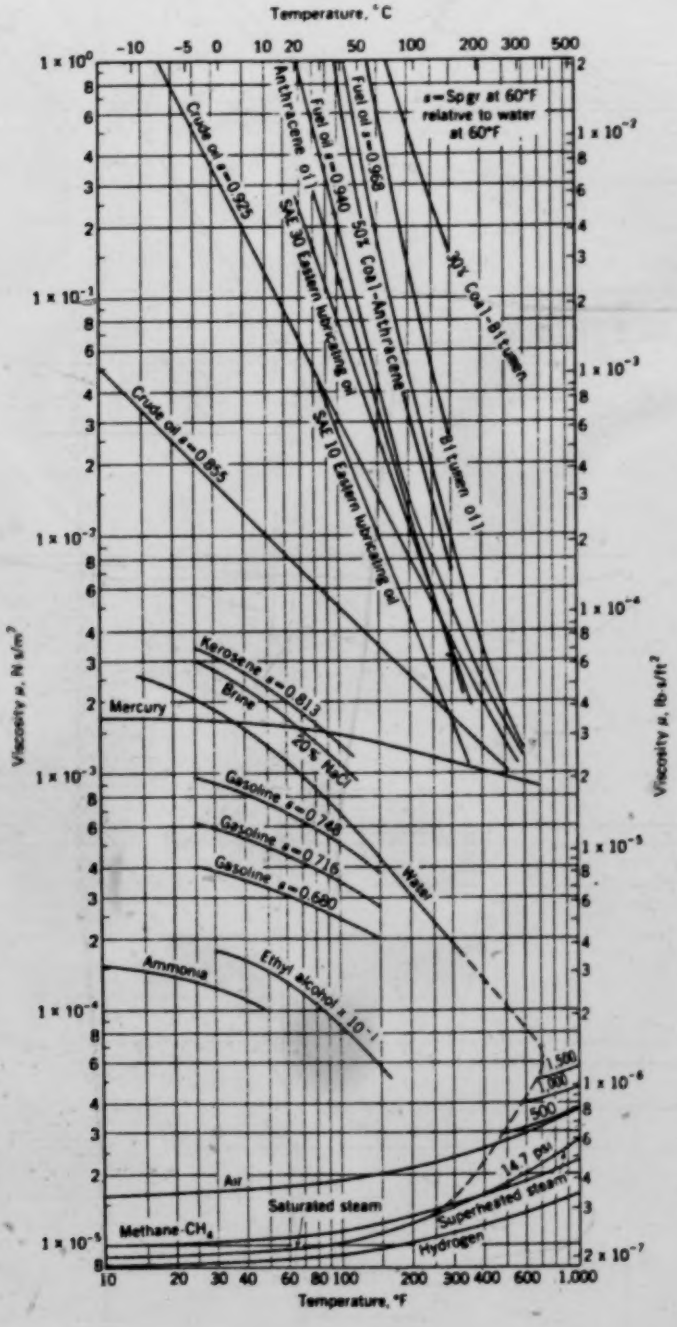

Figure 2.15 Absolute Viscosity of Common Fluids

3. Conclusions and Recommentations

From this work the following conclusions may be drawn regarding the viscous behaviour of coal-anthracene oil and coal-bitumen slurries:

1. Increasing coal concentration imposed a shear thinning (pseudoplastic) tendency on the flow curves for both types of slurry tested. This pseudoplastic effect did not become significant, however, until the coal concentration was 50% by weight.

2. The temperature dependence of the apparent slurry viscosity may be modelled using the activation energy concept. The activation energy of flow was determined by the solvent and was generally independent of coal concentration for the two solvents used in this work.

3. The concentration dependence of reduced slurry viscosity, for coal concentrations under 30%, could be correlated using Einstein's equation. The effect of coal concentration on reduced viscosity was greater than that typically reported in the literature.

A recommendation for future work would be to repeat the experiments in a sealed vessel (eliminating solvent evaporation) to confirm the second conclusion.

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APPENDIX A

COAL PARTICLE SIZE DISTRIBUTION

APPENDIX A

PARTICLE SIZE ANALYSIS

PROGRAM VERSION: 2.5
LAST UPDATE: March 4. 1982

JOB NUMBER: 1845

SAMPLE NUMBER: COA

SAMPLE WEIGHT: 127.50 g.

WET SIEVING:

Initial Weight:	127.50 g.	
+325 Mesh Fraction:	92.49 g.	
-325 Mesh Fraction:	33.68 g.	
Weight Loss	1.33 g.	(1.04)

DRY SIEVING:

Initial Weight:	92.49 g.	
+400 Mesh Fraction:	84.98 g.	
-400 Mesh Fraction:	7.59 g.	
Weight Loss:	-0.08 g.	(-0.09%)

PARTICLE SIZE mesh	phi	microns	FRACTIONAL WEIGHT	CUMULATIVE WEIGHT	FRACTIONAL PERCENT	CUMULATIVE PERCENT
18	0.00	1000.0	0.00	0.00	0.00	0.00
25	0.50	710.0	0.00	0.00	0.00	0.00
35	1.00	500.0	0.00	0.00	0.00	0.00
45	1.50	350.0	0.02	0.02	0.02	0.02
60	2.00	250.0	0.00	0.02	0.00	0.02
80	2.50	177.0	0.00	0.02	0.00	0.02
120	3.00	125.0	13.32	13.34	10.55	10.57
170	3.50	88.0	28.10	41.44	22.26	32.82
230	4.00	62.5	14.61	56.05	11.57	44.40
325	4.50	44.0	23.24	79.29	18.41	62.80
400	4.75	31.0	5.69	84.98	4.51	67.31
	5.30	25.4	7.71	112.82	6.10	89.37
	5.63	20.2	4.10	116.93	3.25	92.62
	5.97	16.0	2.65	119.58	2.10	94.72
	6.30	12.7	1.99	121.57	1.58	96.29
	6.63	10.1	1.49	123.06	1.18	97.47
	6.97	8.0	1.12	124.18	0.89	98.36
	7.30	6.3	0.75	124.92	0.59	98.95
	7.63	5.0	0.54	125.46	0.43	99.38
	7.97	4.0	0.41	125.88	0.33	99.70
	8.30	3.2	0.25	126.13	0.20	99.90
	8.63	2.5	0.12	126.25	0.10	100.00

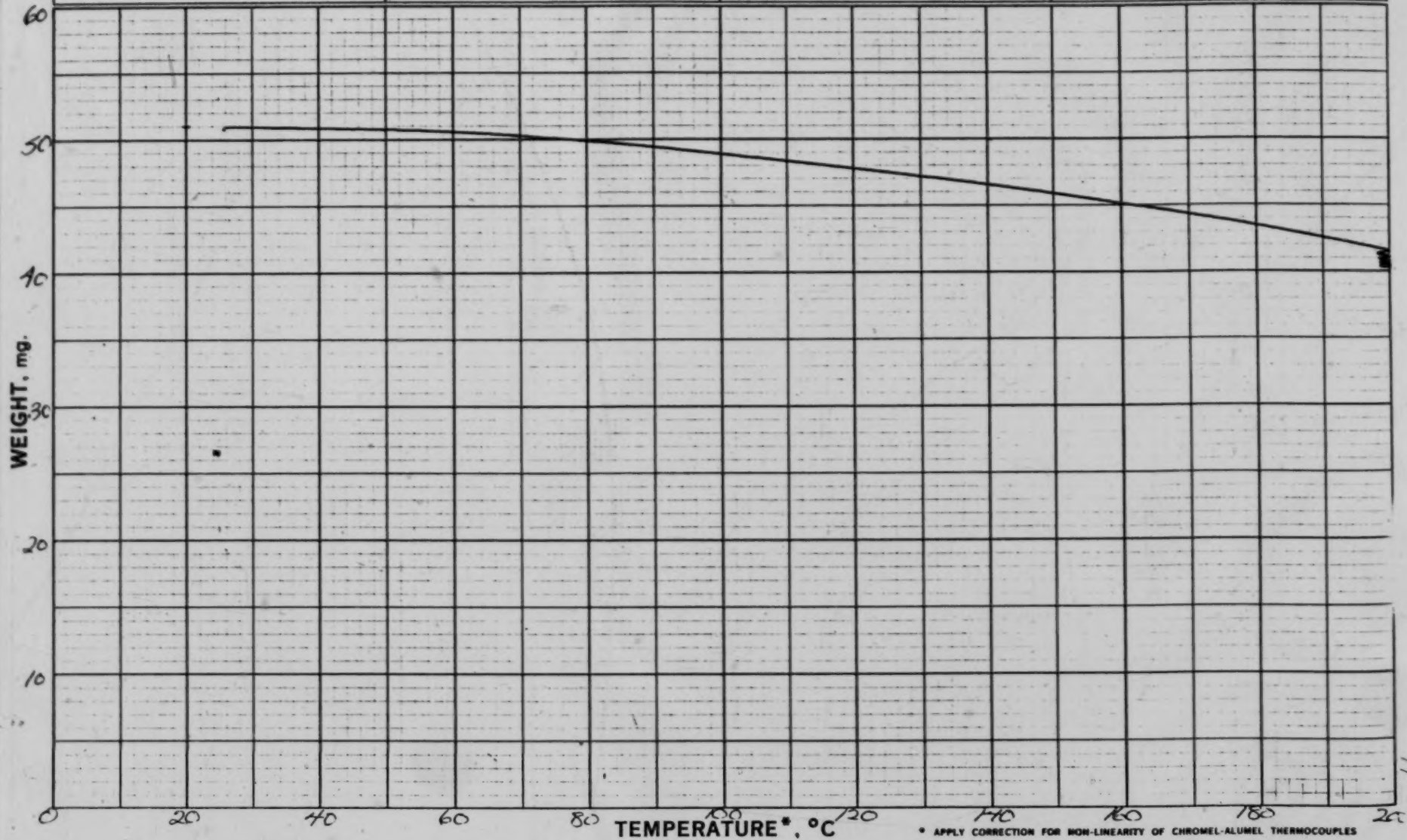
APPENDIX B

TGA CURVES FOR COAL-BITUMEN SLURRIES

PART NO. 950017

DUPONT INSTRUMENTS

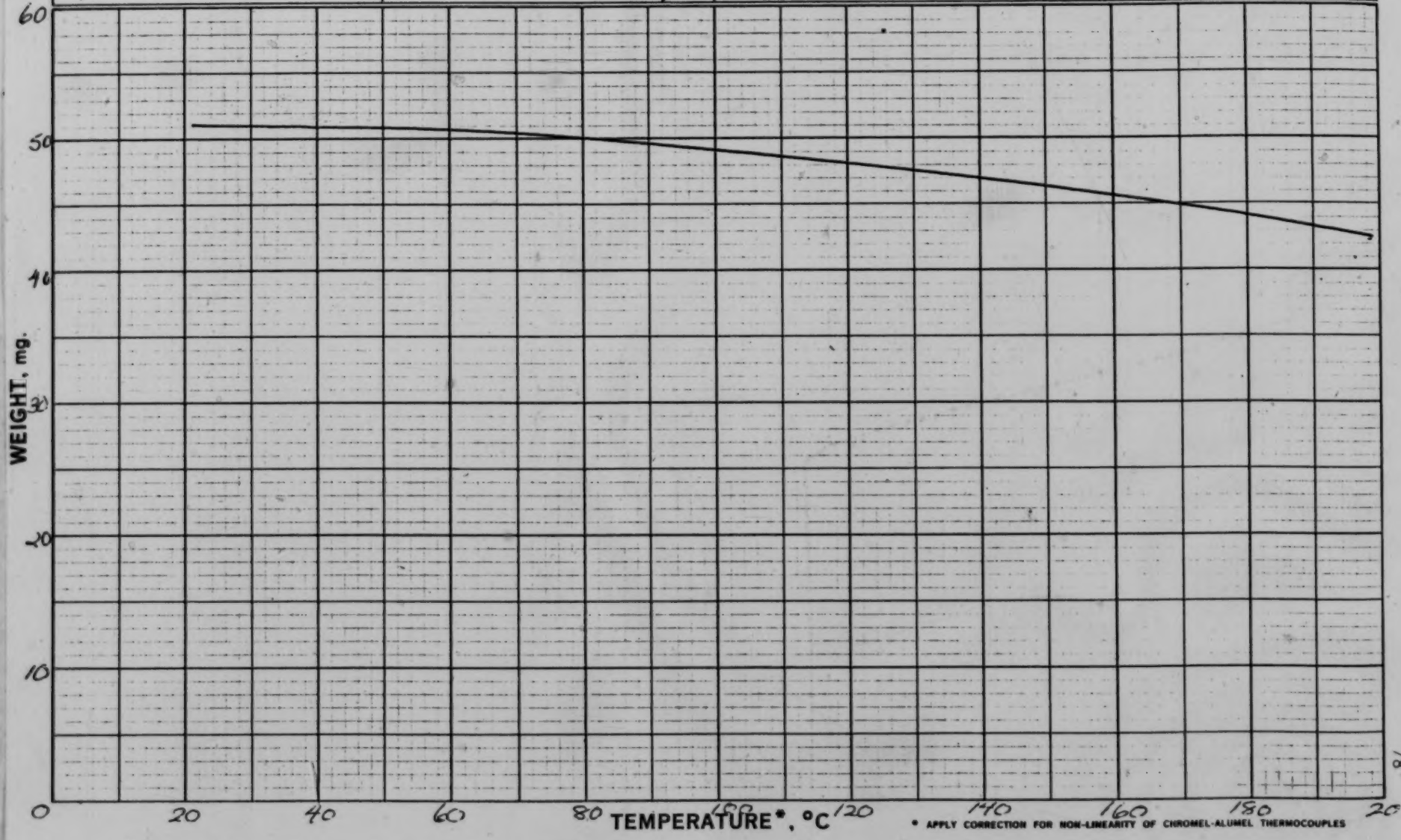
SAMPLE:	X-AXIS	Y-AXIS	RUN NO. ____ DATE May/83
S. KOVACIK, ARC BITUMEN	TEMP. SCALE 20 °C/inch	SCALE 10 mg./inch	OPERATOR CM
SIZE ≈ 51.0 mg.	SHIFT 0 inch	[illegible]	HEATING RATE 2. °C/min.
	TIME SCALE (ALT.) Temp	SUPPRESSION 0 mg.	ATM. N_2
			TIME CONSTANT 1 sec.



PART NO. 950017

DUPONT INSTRUMENTS

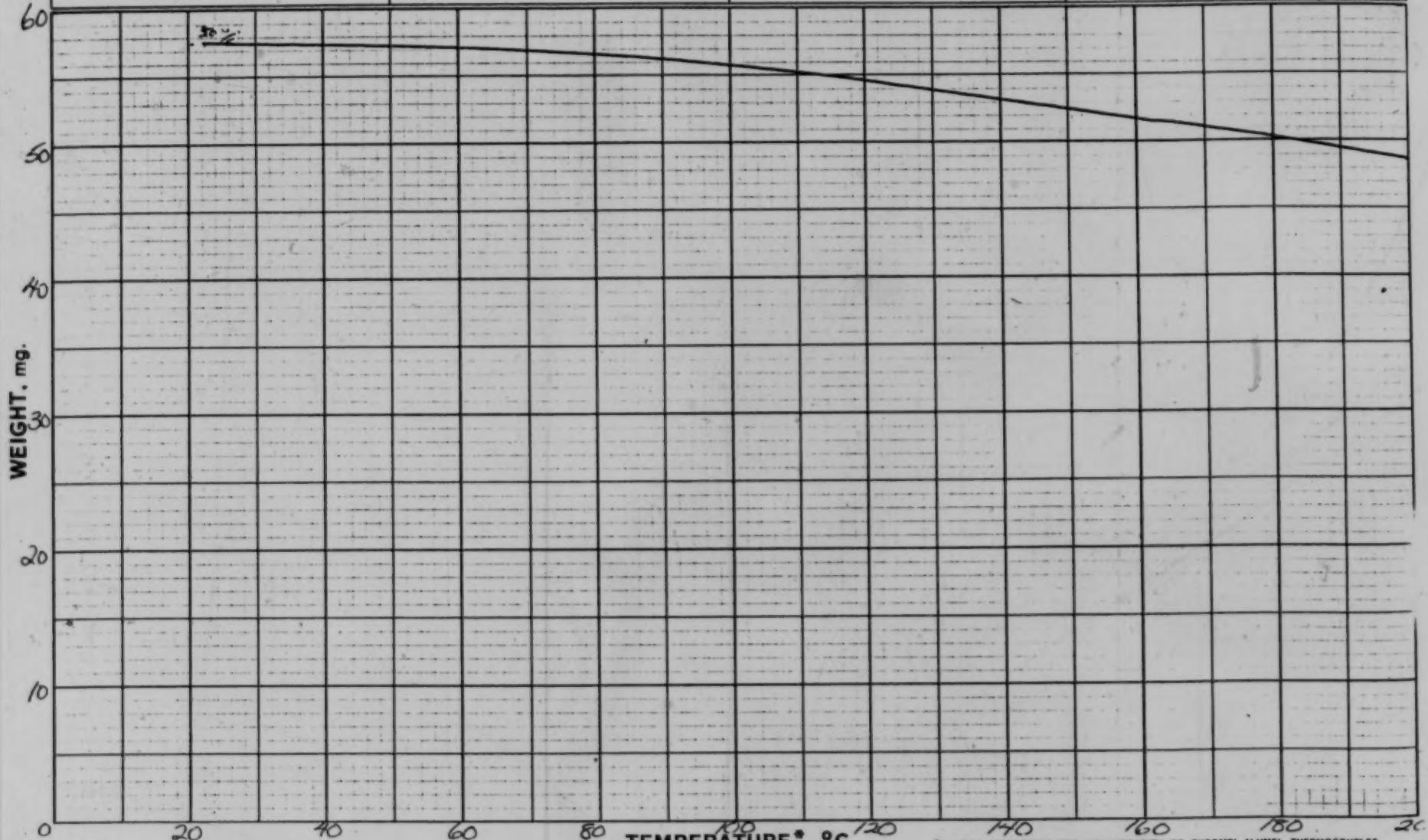
SAMPLE: 10% bit. coal	X-AXIS	Y-AXIS	RUN NO. ____ DATE May 82
	TEMP. SCALE 20 °C / inch	SCALE 10 mg. / inch	OPERATOR CM
	SHIFT 0 inch	~~SCALE SETTING X 2~~	HEATING RATE 2 °C / min.
SIZE ≈ 51.0 mg.	TIME SCALE (ALT.) Temp	SUPPRESSION 0 mg.	ATM. N_2
			TIME CONSTANT 1 sec.



PART NO. 950017

DUPONT INSTRUMENTS

SAMPLE: 30% bit. coal	X-AXIS	Y-AXIS	RUN NO. ____ DATE May/8-
	TEMP. SCALE 20 °C / inch	SCALE 10 mg. / inch	OPERATOR CM
	SHIFT 0 inch	~~(SCALE SETTING X 2)~~	HEATING RATE 2 °C / min.
SIZE ~57.5 mg.	TIME SCALE (ALT.) Temp	SUPPRESSION 0 mg.	ATM. N_2
			TIME CONSTANT 1 sec.



APPENDIX C

DATA

APPENDIX C - DATA

LEGEND

In this appendix the raw data is sorted by oil, coal concentration and heating and cooling modes. The data is arranged in six columns. The first column on the left is the run number; the second column is the coal concentration by weight, the third column is the temperature in degrees celsius; the forth column is the shear rate; the fifth column is the shear stress; the sixth and last column is the apparent viscosity in Pa.s.

ANTHRACENE OIL - HEATING

1	0.0	24.4	17.549999	8.500800	0.484376
1	0.0	24.4	35.099998	15.842401	0.451350
1	0.0	24.4	52.650002	23.570402	0.447681
1	0.0	24.4	70.199997	30.912001	0.440342
1	0.0	24.4	87.750000	38.639999	0.440342
1	0.0	24.4	105.300003	45.981602	0.436672
1	0.0	24.4	122.849991	53.323204	0.434051
1	0.0	24.4	140.399994	60.664803	0.432086
1	0.0	24.4	157.949997	68.006401	0.430557
1	0.0	24.4	175.500000	74.961609	0.427132
2	0.0	30.0	29.249998	5.796000	0.198154
2	0.0	30.0	58.499996	11.205601	0.191549
2	0.0	30.0	87.750000	17.001600	0.193750
2	0.0	30.0	116.999992	22.797600	0.194851
2	0.0	30.0	146.250000	28.593599	0.195512
2	0.0	30.0	175.500000	34.389603	0.195952
2	0.0	30.0	204.749985	40.185600	0.196267
2	0.0	30.0	233.999985	45.595200	0.194851
2	0.0	30.0	263.250000	52.164001	0.198154
2	0.0	30.0	292.500000	56.800804	0.194191
3	0.0	36.4	29.249998	3.187800	0.108985
3	0.0	36.4	58.499996	5.796000	0.099077
3	0.0	36.4	87.750000	8.404201	0.095774
3	0.0	36.4	116.999992	11.012400	0.094123
3	0.0	36.4	146.250000	13.910400	0.095114
3	0.0	36.4	175.500000	16.518600	0.094123
3	0.0	36.4	204.749985	19.416601	0.094831
3	0.0	36.4	233.999985	22.024799	0.094123
3	0.0	36.4	263.250000	24.922800	0.094674
3	0.0	36.4	292.500000	27.531000	0.094123
4	0.0	44.9	58.499996	2.898000	0.049538
4	0.0	44.9	116.999992	5.554500	0.047474
4	0.0	44.9	175.500000	8.211000	0.046786
4	0.0	44.9	233.999985	10.867500	0.046442
4	0.0	44.9	292.500000	13.524000	0.046236
4	0.0	44.9	351.000000	16.422001	0.046786
4	0.0	44.9	409.499969	19.078501	0.046590
4	0.0	44.9	467.999969	22.459501	0.047990
4	0.0	44.9	526.500000	24.633001	0.046786
4	0.0	44.9	585.000000	31.878000	0.054492
5	0.0	53.3	70.199997	1.738800	0.024769
5	0.0	53.3	140.399994	3.284400	0.023393
5	0.0	53.3	210.600006	5.023200	0.023852
5	0.0	53.3	280.799988	6.568800	0.023393
5	0.0	53.3	351.000000	8.307600	0.023668
5	0.0	53.3	421.200012	9.853200	0.023393
5	0.0	53.3	491.399963	11.785201	0.023983
5	0.0	53.3	561.599976	13.330801	0.023737
5	0.0	53.3	631.799988	15.069600	0.023852
5	0.0	53.3	702.000000	16.808401	0.023944
6	0.0	61.3	70.199997	1.159200	0.016513
6	0.0	61.3	140.399994	2.221800	0.015825
6	0.0	61.3	210.600006	3.284400	0.015595
6	0.0	61.3	280.799988	4.347000	0.015481
6	0.0	61.3	351.000000	5.409600	0.015412
6	0.0	61.3	421.200012	6.472200	0.015366
6	0.0	61.3	491.399963	7.631400	0.015530
6	0.0	61.3	561.599976	8.790601	0.015653
6	0.0	61.3	631.799988	9.949800	0.015748
6	0.0	61.3	702.000000	11.109000	0.015825
7	0.0	71.6	81.899994	0.772800	0.009436

7	0.0	71.6	163.799988	1.642200	0.010026
7	0.0	71.6	245.699997	2.415000	0.009829
7	0.0	71.6	327.599976	3.187800	0.009731
7	0.0	71.6	409.500000	3.960600	0.009672
7	0.0	71.6	491.399994	4.830000	0.009829
7	0.0	71.6	573.299988	5.699400	0.009941
7	0.0	71.6	655.199951	6.568800	0.010026
7	0.0	71.6	737.099976	7.534800	0.010222
7	0.0	71.6	819.000000	8.404201	0.010262
8	0.0	81.2	81.899994	0.579600	0.007077
8	0.0	81.2	163.799988	1.086750	0.006635
8	0.0	81.2	245.699997	1.666350	0.006782
8	0.0	81.2	327.599976	2.245950	0.006856
8	0.0	81.2	409.500000	2.825550	0.006900
8	0.0	81.2	491.399994	3.405150	0.006929
8	0.0	81.2	573.299988	4.057200	0.007077
8	0.0	81.2	655.199951	4.709250	0.007188
8	0.0	81.2	737.099976	5.288850	0.007175
8	0.0	81.2	819.000000	4.564350	0.005573
9	0.0	90.4	93.599998	0.652050	0.006966
9	0.0	90.4	187.199997	1.086750	0.005805
9	0.0	90.4	280.799988	1.593900	0.005676
9	0.0	90.4	374.399994	2.101050	0.005612
9	0.0	90.4	468.000000	2.608200	0.005573
9	0.0	90.4	561.599976	3.187800	0.005676
9	0.0	90.4	655.199951	3.694950	0.005639
9	0.0	90.4	748.799988	4.274550	0.005709
9	0.0	90.4	842.399963	4.854150	0.005762
9	0.0	90.4	936.000000	5.506200	0.005883
10	0.0	101.1	105.299995	0.652050	0.006192
10	0.0	101.1	210.599991	1.014300	0.004816
10	0.0	101.1	315.899994	1.449000	0.004587
10	0.0	101.1	421.199982	1.883700	0.004472
10	0.0	101.1	473.849976	2.173500	0.004587
10	0.0	101.1	526.500000	2.390850	0.004541
10	0.0	101.1	631.799988	2.898000	0.004587
10	0.0	101.1	684.449951	3.187800	0.004657
10	0.0	101.1	737.099976	3.405150	0.004620
10	0.0	101.1	842.399963	3.984750	0.004730
11	0.0	109.6	116.999992	0.743820	0.006357
11	0.0	109.6	175.500000	0.946680	0.005394
11	0.0	109.6	233.999985	1.149540	0.004913
11	0.0	109.6	351.000000	1.487640	0.004238
11	0.0	109.6	467.999969	1.893360	0.004046
11	0.0	109.6	526.500000	2.163840	0.004110
11	0.0	109.6	585.000000	2.366700	0.004046
11	0.0	109.6	643.500000	2.569560	0.003993
11	0.0	109.6	702.000000	2.840040	0.004046
11	0.0	109.6	760.499939	3.110520	0.004090
12	0.0	111.3	116.999992	0.608580	0.005202
12	0.0	111.3	233.999985	1.081920	0.004624
12	0.0	111.3	351.000000	1.622880	0.004624
12	0.0	111.3	409.499969	1.825740	0.004458
12	0.0	111.3	467.999969	2.096220	0.004479
12	0.0	111.3	585.000000	2.637180	0.004508
12	0.0	111.3	643.500000	2.907660	0.004519
12	0.0	111.3	702.000000	3.178140	0.004527
12	0.0	111.3	760.499939	3.448620	0.004535
12	0.0	111.3	818.999939	3.786720	0.004624
13	0.0	131.4	58.499996	0.241500	0.004128
13	0.0	131.4	116.999992	0.338100	0.002890

13	0.0	131.4	175.500000	0.579600	0.003303
13	0.0	131.4	233.999985	0.676200	0.002890
13	0.0	131.4	292.500000	0.821100	0.002807
13	0.0	131.4	351.000000	1.014300	0.002890
13	0.0	131.4	409.499969	1.159200	0.002831
13	0.0	131.4	467.999969	1.352400	0.002890
13	0.0	131.4	526.500000	1.545600	0.002936
13	0.0	131.4	561.599976	1.738800	0.003096
14	0.0	150.4	116.999992	0.241500	0.002064
14	0.0	150.4	233.999985	0.579600	0.002477
14	0.0	150.4	351.000000	0.869400	0.002477
14	0.0	150.4	467.999969	1.207500	0.002580
14	0.0	150.4	585.000000	1.738800	0.002972
14	0.0	150.4	702.000000	2.318400	0.003303
14	0.0	150.4	818.999939	3.042900	0.003715
14	0.0	150.4	935.999939	3.767400	0.004025
14	0.0	150.4	1053.000000	4.636800	0.004403
14	0.0	150.4	1170.000000	5.554500	0.004747

10% w/w COAL-ANTHRACENE OIL - HEATING

17	10.0	21.5	7.200000	12.995000	1.804861
17	10.0	21.5	14.400001	24.295000	1.687153
17	10.0	21.5	21.600000	35.595001	1.647917
17	10.0	21.5	28.800001	46.895000	1.628299
17	10.0	21.5	36.000000	59.324997	1.647917
17	10.0	21.5	43.200001	71.190002	1.647917
17	10.0	21.5	50.399998	81.925003	1.625496
17	10.0	21.5	57.600002	96.050003	1.667535
17	10.0	21.5	64.799995	107.350006	1.656636
17	10.0	21.5	69.840004	113.000000	1.617984
18	10.0	28.8	18.000000	8.475000	0.470833
18	10.0	28.8	36.000000	15.820000	0.439444
18	10.0	28.8	54.000000	23.164999	0.428981
18	10.0	28.8	72.000000	29.944998	0.415903
18	10.0	28.8	90.000000	37.290001	0.414333
18	10.0	28.8	108.000000	45.200001	0.418519
18	10.0	28.8	125.999992	52.544998	0.417024
18	10.0	28.8	144.000000	59.324997	0.411979
18	10.0	28.8	161.999985	66.104996	0.408056
18	10.0	28.8	180.000000	73.449997	0.408056
19	10.0	36.5	45.000000	6.215000	0.138111
19	10.0	36.5	90.000000	11.865000	0.131833
19	10.0	36.5	135.000000	18.645000	0.138111
19	10.0	36.5	180.000000	23.730000	0.131833
19	10.0	36.5	225.000000	30.510002	0.135600
19	10.0	36.5	270.000000	37.855000	0.140204
19	10.0	36.5	315.000000	45.200001	0.143492
19	10.0	36.5	360.000000	51.415001	0.142819
19	10.0	36.5	404.999969	59.889996	0.147877
19	10.0	36.5	450.000000	66.104996	0.146900
20	10.0	47.0	45.000000	2.825000	0.062778
20	10.0	47.0	90.000000	5.085000	0.056500
20	10.0	47.0	135.000000	7.627501	0.056500
20	10.0	47.0	180.000000	10.170000	0.056500
20	10.0	47.0	225.000000	13.277499	0.059011
20	10.0	47.0	270.000000	15.820000	0.058593
20	10.0	47.0	315.000000	18.927500	0.060087
20	10.0	47.0	360.000000	21.469999	0.059639
20	10.0	47.0	404.999969	24.295000	0.059988
20	10.0	47.0	450.000000	27.120001	0.060267
21	10.0	48.0	45.000000	2.034000	0.045200
21	10.0	48.0	90.000000	4.294000	0.047711
21	10.0	48.0	135.000000	6.780000	0.050222
21	10.0	48.0	180.000000	9.492000	0.052733
21	10.0	48.0	225.000000	11.978000	0.053236
21	10.0	48.0	270.000000	14.690000	0.054407
21	10.0	48.0	315.000000	17.401999	0.055244
21	10.0	48.0	360.000000	20.114000	0.055872
21	10.0	48.0	404.999969	23.051998	0.056919
21	10.0	48.0	450.000000	25.764000	0.057253
22	10.0	59.8	45.000000	1.525500	0.033900
22	10.0	59.8	90.000000	2.712000	0.030133
22	10.0	59.8	135.000000	4.068000	0.030133
22	10.0	59.8	180.000000	5.424000	0.030133
22	10.0	59.8	225.000000	6.780000	0.030133
22	10.0	59.8	270.000000	8.305500	0.030761
22	10.0	59.8	315.000000	9.830999	0.031210
22	10.0	59.8	360.000000	11.356500	0.031546
22	10.0	59.8	404.999969	12.882000	0.031807
22	10.0	59.8	450.000000	14.746500	0.032770
23	10.0	68.5	45.000000	0.565000	0.012556

23	10.0	68.5	90.000000	1.356000	0.015067
23	10.0	68.5	135.000000	2.034000	0.015067
23	10.0	68.5	157.500000	2.486000	0.015784
23	10.0	68.5	180.000000	2.938000	0.016322
23	10.0	68.5	202.499985	3.277000	0.016183
23	10.0	68.5	225.000000	3.729000	0.016573
23	10.0	68.5	247.500015	4.181000	0.016893
23	10.0	68.5	270.000000	4.633000	0.017159
23	10.0	68.5	292.500000	5.085000	0.017385
24	10.0	79.5	22.500000	0.452000	0.020089
24	10.0	79.5	45.000000	0.678000	0.015067
24	10.0	79.5	67.500000	0.904000	0.013393
24	10.0	79.5	90.000000	1.017000	0.011300
24	10.0	79.5	112.500000	1.356000	0.012053
24	10.0	79.5	135.000000	1.582000	0.011719
24	10.0	79.5	157.500000	1.808000	0.011479
24	10.0	79.5	171.000000	1.921000	0.011234
24	10.0	79.5	180.000000	2.147000	0.011928
24	10.0	79.5	198.000000	2.373000	0.011985
25	10.0	104.8	22.500000	0.169500	0.007533
25	10.0	104.8	45.000000	0.282500	0.006278
25	10.0	104.8	67.500000	0.395500	0.005859
25	10.0	104.8	90.000000	0.508500	0.005650
25	10.0	104.8	112.500000	0.791000	0.007031
25	10.0	104.8	135.000000	1.073500	0.007952
25	10.0	104.8	157.500000	1.412500	0.008968
25	10.0	104.8	180.000000	1.751500	0.009731
25	10.0	104.8	202.499985	2.090500	0.010323
25	10.0	104.8	225.000000	2.486000	0.011049
26	10.0	124.6	45.000000	0.226000	0.005022
26	10.0	124.6	67.500000	0.339000	0.005022
26	10.0	124.6	90.000000	0.452000	0.005022
26	10.0	124.6	112.500000	0.621500	0.005524
26	10.0	124.6	123.750008	0.791000	0.006392
26	10.0	124.6	135.000000	0.904000	0.006696
26	10.0	124.6	157.500000	1.130000	0.007175
26	10.0	124.6	180.000000	1.412500	0.007847
26	10.0	124.6	202.499985	1.695000	0.008370
26	10.0	124.6	225.000000	1.977500	0.008789
27	10.0	148.4	22.500000	0.056500	0.002511
27	10.0	148.4	45.000000	0.113000	0.002511
27	10.0	148.4	67.500000	0.226000	0.003348
27	10.0	148.4	90.000000	0.339000	0.003767
27	10.0	148.4	112.500000	0.508500	0.004520
27	10.0	148.4	135.000000	0.678000	0.005022
27	10.0	148.4	157.500000	0.904000	0.005740
27	10.0	148.4	180.000000	1.130000	0.006278
27	10.0	148.4	202.499985	1.356000	0.006696
27	10.0	148.4	225.000000	1.582000	0.007031

30% w/w COAL-ANTHRACENE OIL - HEATING

29	30.0	23.3	0.450000	12.429999	27.622219
29	30.0	23.3	0.900000	21.469999	23.855555
29	30.0	23.3	1.350000	29.944998	22.181479
29	30.0	23.3	1.800000	37.855000	21.030554
29	30.0	23.3	2.250000	45.764999	20.340000
29	30.0	23.3	2.700000	51.980000	19.251852
29	30.0	23.3	3.150000	58.759998	18.653969
29	30.0	23.3	3.600000	64.410004	17.891666
29	30.0	23.3	4.050000	71.754997	17.717285
29	30.0	23.3	4.500000	76.840004	17.075556
30	30.0	37.4	15.750001	9.040000	0.573968
30	30.0	37.4	31.500002	18.080000	0.573968
30	30.0	37.4	47.250000	25.990000	0.550053
30	30.0	37.4	63.000004	34.465000	0.547063
30	30.0	37.4	78.750000	42.375000	0.538095
30	30.0	37.4	94.500000	49.154999	0.520159
30	30.0	37.4	110.249992	55.935001	0.507347
30	30.0	37.4	126.000008	63.279999	0.502222
30	30.0	37.4	141.749985	68.930000	0.486279
30	30.0	37.4	157.500000	74.580002	0.473524
31	30.0	45.3	33.750000	7.910000	0.234370
31	30.0	45.3	67.500000	15.820000	0.234370
31	30.0	45.3	101.250000	23.730000	0.234370
31	30.0	45.3	135.000000	30.510002	0.226000
31	30.0	45.3	168.750000	37.855000	0.224326
31	30.0	45.3	202.500000	44.635002	0.220420
31	30.0	45.3	236.249985	51.980000	0.220021
31	30.0	45.3	270.000000	58.759998	0.217630
31	30.0	45.3	303.749969	65.540001	0.215770
31	30.0	45.3	337.500000	72.320000	0.214281
32	30.0	52.5	33.750000	4.068000	0.120533
32	30.0	52.5	67.500000	7.797000	0.115511
32	30.0	52.5	101.250000	11.865000	0.117185
32	30.0	52.5	135.000000	15.933000	0.118022
32	30.0	52.5	168.750000	20.000998	0.118524
32	30.0	52.5	202.500000	24.747002	0.122207
32	30.0	52.5	236.249985	27.798000	0.117664
32	30.0	52.5	270.000000	32.205002	0.119278
32	30.0	52.5	303.749969	36.272999	0.119417
32	30.0	52.5	337.500000	40.001995	0.118524
33	30.0	62.8	36.000000	2.034000	0.056500
33	30.0	62.8	72.000000	3.842000	0.053361
33	30.0	62.8	108.000000	5.650000	0.052315
33	30.0	62.8	144.000000	7.458000	0.051792
33	30.0	62.8	180.000000	9.266000	0.051478
33	30.0	62.8	216.000000	11.074000	0.051269
33	30.0	62.8	251.999985	13.108000	0.052016
33	30.0	62.8	288.000000	14.916000	0.051792
33	30.0	62.8	323.999969	16.950001	0.052315
33	30.0	62.8	360.000000	18.757999	0.052106
34	30.0	72.0	36.000000	1.271250	0.035312
34	30.0	72.0	72.000000	2.260000	0.031389
34	30.0	72.0	108.000000	3.390000	0.031389
34	30.0	72.0	144.000000	4.520000	0.031389
34	30.0	72.0	180.000000	5.650000	0.031389
34	30.0	72.0	216.000000	6.780000	0.031389
34	30.0	72.0	251.999985	8.051250	0.031949
34	30.0	72.0	288.000000	9.322500	0.032370
34	30.0	72.0	323.999969	10.735000	0.033133
34	30.0	72.0	360.000000	12.147500	0.033743
35	30.0	79.5	36.000000	0.904000	0.025111

35	30.0	79.5	72.000000	1.808000	0.025111
35	30.0	79.5	108.000000	2.599000	0.024065
35	30.0	79.5	144.000000	3.503000	0.024326
35	30.0	79.5	180.000000	4.407000	0.024483
35	30.0	79.5	216.000000	5.424000	0.025111
35	30.0	79.5	251.999985	6.328000	0.025111
35	30.0	79.5	288.000000	7.345000	0.025503
35	30.0	79.5	323.999969	8.475000	0.026157
35	30.0	79.5	360.000000	9.605000	0.026681
36	30.0	89.8	45.000000	0.904000	0.020089
36	30.0	89.8	90.000000	1.695000	0.018833
36	30.0	89.8	135.000000	2.486000	0.018415
36	30.0	89.8	180.000000	3.390000	0.018833
36	30.0	89.8	202.499985	3.842000	0.018973
36	30.0	89.8	225.000000	4.294000	0.019084
36	30.0	89.8	270.000000	5.311000	0.019670
36	30.0	89.8	292.500000	5.876000	0.020089
36	30.0	89.8	315.000000	6.441000	0.020448
36	30.0	89.8	337.500000	7.006001	0.020759
37	30.0	109.0	36.000000	0.678000	0.018833
37	30.0	109.0	72.000000	1.101750	0.015302
37	30.0	109.0	108.000000	1.610250	0.014910
37	30.0	109.0	125.999992	1.864500	0.014798
37	30.0	109.0	144.000000	2.118750	0.014714
37	30.0	109.0	161.999985	2.373000	0.014648
37	30.0	109.0	180.000000	2.627250	0.014596
37	30.0	109.0	198.000015	2.881500	0.014553
37	30.0	109.0	216.000000	3.135750	0.014517
37	30.0	109.0	234.000000	3.474750	0.014849
38	30.0	126.8	36.000000	0.508500	0.014125
38	30.0	126.8	54.000000	0.678000	0.012556
38	30.0	126.8	72.000000	0.847500	0.011771
38	30.0	126.8	90.000000	1.017000	0.011300
38	30.0	126.8	108.000000	1.186500	0.010986
38	30.0	126.8	125.999992	1.356000	0.010762
38	30.0	126.8	144.000000	1.610250	0.011182
38	30.0	126.8	161.999985	1.779750	0.010986
38	30.0	126.8	180.000000	2.034000	0.011300
38	30.0	126.8	198.000015	2.373000	0.011985
39	30.0	136.6	31.500002	0.452000	0.014349
39	30.0	136.6	47.250000	0.621500	0.013153
39	30.0	136.6	63.000004	0.734500	0.011659
39	30.0	136.6	78.750000	0.847500	0.010762
39	30.0	136.6	94.500000	0.960500	0.010164
39	30.0	136.6	110.249992	1.073500	0.009737
39	30.0	136.6	126.000008	1.243000	0.009865
39	30.0	136.6	141.749985	1.469000	0.010363
39	30.0	136.6	157.500000	1.638500	0.010403
39	30.0	136.6	173.250015	1.921000	0.011088
40	30.0	146.6	31.500002	0.339000	0.010762
40	30.0	146.6	63.000004	0.508500	0.008071
40	30.0	146.6	78.750000	0.621500	0.007892
40	30.0	146.6	94.500000	0.678000	0.007175
40	30.0	146.6	110.249992	0.791000	0.007175
40	30.0	146.6	126.000008	0.904000	0.007175
40	30.0	146.6	141.749985	1.130000	0.007972
40	30.0	146.6	157.500000	1.299500	0.008251
40	30.0	146.6	173.250015	1.582000	0.009131
40	30.0	146.6	189.000000	1.864500	0.009865

50% w/w COAL-ANTHRACENE OIL - HEATING

46	50.0	36.3	0.900000	14.690000	16.322222
46	50.0	36.3	1.800000	26.554998	14.752776
46	50.0	36.3	2.700000	38.420002	14.229630
46	50.0	36.3	3.600000	49.154999	13.654166
46	50.0	36.3	4.500000	59.889996	13.308887
46	50.0	36.3	5.400000	70.060005	12.974074
46	50.0	36.3	6.300000	80.229996	12.734921
46	50.0	36.3	7.200000	89.834999	12.477082
46	50.0	36.3	8.099999	98.875000	12.206791
46	50.0	36.3	9.000000	107.350006	11.927778
47	50.0	44.5	1.350000	13.560000	10.044445
47	50.0	44.5	2.700000	24.295000	8.998148
47	50.0	44.5	4.050000	34.465000	8.509876
47	50.0	44.5	5.400000	44.070000	8.161111
47	50.0	44.5	6.750000	53.109997	7.868148
47	50.0	44.5	8.100000	61.020004	7.533333
47	50.0	44.5	9.450000	68.930000	7.294180
47	50.0	44.5	10.800000	77.404999	7.167130
47	50.0	44.5	12.150000	85.315002	7.021811
47	50.0	44.5	13.500000	91.529999	6.780000
48	50.0	54.2	6.750000	14.125000	2.092592
48	50.0	54.2	13.500001	25.424999	1.883333
48	50.0	54.2	20.250000	35.595001	1.757778
48	50.0	54.2	27.000002	45.200001	1.674074
48	50.0	54.2	33.750000	54.805000	1.623852
48	50.0	54.2	40.500000	63.844997	1.576420
48	50.0	54.2	47.249996	72.320000	1.530582
48	50.0	54.2	54.000004	80.794998	1.496204
48	50.0	54.2	60.749996	88.705002	1.460165
48	50.0	54.2	67.500000	94.919998	1.406222
49	50.0	64.2	18.000000	12.429999	0.690556
49	50.0	64.2	36.000000	23.164999	0.643472
49	50.0	64.2	54.000000	32.770000	0.606852
49	50.0	64.2	72.000000	41.810001	0.580694
49	50.0	64.2	90.000000	50.285000	0.558722
49	50.0	64.2	108.000000	58.759998	0.544074
49	50.0	64.2	125.999992	67.235008	0.533611
49	50.0	64.2	144.000000	75.144997	0.521840
49	50.0	64.2	161.999985	83.620003	0.516173
49	50.0	64.2	180.000000	90.400002	0.502222
50	50.0	74.3	33.750000	13.560000	0.401778
50	50.0	74.3	67.500000	25.990000	0.385037
50	50.0	74.3	101.250000	37.290001	0.368296
50	50.0	74.3	135.000000	46.895000	0.347370
50	50.0	74.3	168.750000	57.064999	0.338163
50	50.0	74.3	202.500000	66.104996	0.326444
50	50.0	74.3	236.249985	74.580002	0.315683
50	50.0	74.3	270.000000	83.055000	0.307611
50	50.0	74.3	303.749969	88.139999	0.290173
50	50.0	74.3	337.500000	93.790001	0.277896
51	50.0	84.3	22.500000	6.780000	0.301333
51	50.0	84.3	45.000000	11.865000	0.263667
51	50.0	84.3	67.500000	18.080000	0.267852
51	50.0	84.3	90.000000	23.164999	0.257389
51	50.0	84.3	112.500000	28.250000	0.251111
51	50.0	84.3	135.000000	33.334999	0.246926
51	50.0	84.3	180.000000	41.810001	0.232278
51	50.0	84.3	202.499985	46.329998	0.228790
51	50.0	84.3	225.000000	50.285000	0.223489
51	50.0	84.3	270.000000	58.195000	0.215537
52	50.0	93.6	27.000002	4.972000	0.184148

52	50.0	93.6	54.000004	9.040000	0.167407
52	50.0	93.6	81.000000	13.108000	0.161827
52	50.0	93.6	108.000008	16.724001	0.154852
52	50.0	93.6	135.000000	20.792000	0.154015
52	50.0	93.6	162.000000	24.408003	0.150667
52	50.0	93.6	188.999985	28.024002	0.148275
52	50.0	93.6	216.000015	31.640001	0.146481
52	50.0	93.6	242.999985	35.256001	0.145086
52	50.0	93.6	270.000000	38.872002	0.143970
53	50.0	112.6	36.000000	5.085000	0.141250
53	50.0	112.6	72.000000	9.153001	0.127125
53	50.0	112.6	108.000000	13.221000	0.122417
53	50.0	112.6	144.000000	17.628000	0.122417
53	50.0	112.6	180.000000	22.035000	0.122417
53	50.0	112.6	216.000000	26.441999	0.122417
53	50.0	112.6	251.999985	31.188000	0.123762
53	50.0	112.6	288.000000	35.256001	0.122417
53	50.0	112.6	323.999969	39.662998	0.122417
53	50.0	112.6	360.000000	43.730995	0.121475
54	50.0	123.2	18.000000	1.977500	0.109861
54	50.0	123.2	36.000000	3.361750	0.093382
54	50.0	123.2	54.000000	4.746000	0.087889
54	50.0	123.2	72.000000	6.130250	0.085142
54	50.0	123.2	90.000000	7.712250	0.085692
54	50.0	123.2	108.000000	9.096500	0.084227
54	50.0	123.2	125.999992	10.480749	0.083181
54	50.0	123.2	144.000000	11.865001	0.082396
54	50.0	123.2	161.999985	13.447001	0.083006
54	50.0	123.2	180.000000	15.029000	0.083494
55	50.0	132.0	31.500002	3.164000	0.100444
55	50.0	132.0	63.000004	6.130250	0.097306
55	50.0	132.0	94.500000	8.898749	0.094167
55	50.0	132.0	126.000008	11.667249	0.092597
55	50.0	132.0	157.500000	14.633500	0.092911
55	50.0	132.0	189.000000	17.599751	0.093120
55	50.0	132.0	220.499985	20.961498	0.095063
55	50.0	132.0	252.000015	24.125500	0.095736
55	50.0	132.0	283.499969	27.091749	0.095562
55	50.0	132.0	315.000000	30.058001	0.095422
56	50.0	144.8	27.000002	3.390000	0.125556
56	50.0	144.8	54.000004	6.102000	0.113000
56	50.0	144.8	81.000000	8.475000	0.104630
56	50.0	144.8	108.000008	10.678500	0.098875
56	50.0	144.8	135.000000	12.712501	0.094167
56	50.0	144.8	162.000000	14.915999	0.092074
56	50.0	144.8	188.999985	16.780500	0.088786
56	50.0	144.8	216.000015	18.645000	0.086319
56	50.0	144.8	242.999985	20.509501	0.084401
56	50.0	144.8	270.000000	22.204500	0.082239
57	50.0	144.8	27.000002	2.203500	0.081611
57	50.0	144.8	54.000004	3.729000	0.069056
57	50.0	144.8	81.000000	5.593500	0.069056
57	50.0	144.8	108.000008	7.458000	0.069056
57	50.0	144.8	135.000000	9.661500	0.071567
57	50.0	144.8	162.000000	11.695499	0.072194
57	50.0	144.8	188.999985	14.238000	0.075333
57	50.0	144.8	216.000015	16.611000	0.076903
57	50.0	144.8	242.999985	19.492500	0.080216
57	50.0	144.8	270.000000	22.204500	0.082239

ANTHRACENE OIL - COOLING

15	0.0	101.0	93.599998	0.724500	0.007740
15	0.0	101.0	187.199997	1.231650	0.006579
15	0.0	101.0	280.799988	1.811250	0.006450
15	0.0	101.0	374.399994	2.535750	0.006773
15	0.0	101.0	468.000000	3.042900	0.006502
15	0.0	101.0	561.599976	3.694950	0.006579
15	0.0	101.0	655.199951	4.347000	0.006635
15	0.0	101.0	748.799988	5.071500	0.006773
15	0.0	101.0	842.399963	5.723550	0.006794
15	0.0	101.0	936.000000	6.375600	0.006812
16	0.0	42.0	58.499996	8.114400	0.138708
16	0.0	42.0	116.999992	15.890701	0.135818
16	0.0	42.0	146.250000	19.609800	0.134084
16	0.0	42.0	175.500000	23.328901	0.132928
16	0.0	42.0	233.999985	31.105202	0.132928
16	0.0	42.0	292.500000	38.543400	0.131772
16	0.0	42.0	321.750000	42.600601	0.132403
16	0.0	42.0	351.000000	46.319702	0.131965
16	0.0	42.0	409.499969	53.757900	0.131277
16	0.0	42.0	467.999969	61.534203	0.131483
127	0.0	125.6	13.500001	0.226000	0.016741
127	0.0	125.6	27.000002	0.282500	0.010463
127	0.0	125.6	40.500000	0.339000	0.008370
127	0.0	125.6	54.000004	0.372900	0.006906
127	0.0	125.6	67.500000	0.452000	0.006696
127	0.0	125.6	81.000000	0.565000	0.006975
127	0.0	125.6	94.499992	0.678000	0.007175
127	0.0	125.6	108.000008	0.791000	0.007324
127	0.0	125.6	121.499992	0.904000	0.007440
127	0.0	125.6	135.000000	1.017000	0.007533
128	0.0	107.0	13.500001	0.169500	0.012556
128	0.0	107.0	27.000002	0.203400	0.007533
128	0.0	107.0	40.500000	0.271200	0.006696
128	0.0	107.0	54.000004	0.339000	0.006278
128	0.0	107.0	67.500000	0.423750	0.006278
128	0.0	107.0	81.000000	0.508500	0.006278
128	0.0	107.0	94.499992	0.644100	0.006816
128	0.0	107.0	108.000008	0.762750	0.007062
128	0.0	107.0	121.499992	0.932250	0.007673
128	0.0	107.0	135.000000	1.101750	0.008161
129	0.0	88.1	18.000000	0.254250	0.014125
129	0.0	88.1	36.000000	0.339000	0.009417
129	0.0	88.1	54.000000	0.457650	0.008475
129	0.0	88.1	72.000000	0.593250	0.008240
129	0.0	88.1	90.000000	0.711900	0.007910
129	0.0	88.1	108.000000	0.881400	0.008161
129	0.0	88.1	125.999992	1.033950	0.008206
129	0.0	88.1	144.000000	1.356000	0.009417
129	0.0	88.1	161.999985	1.610250	0.009940
129	0.0	88.1	180.000000	1.949250	0.010829
130	0.0	69.9	18.000000	0.339000	0.018833
130	0.0	69.9	36.000000	0.508500	0.014125
130	0.0	69.9	54.000000	0.762750	0.014125
130	0.0	69.9	72.000000	0.983100	0.013654
130	0.0	69.9	90.000000	1.186500	0.013183
130	0.0	69.9	108.000000	1.440750	0.013340
130	0.0	69.9	125.999992	1.661100	0.013183
130	0.0	69.9	144.000000	1.915350	0.013301
130	0.0	69.9	161.999985	2.169600	0.013393
130	0.0	69.9	180.000000	2.457750	0.013654
131	0.0	49.8	18.000000	0.932250	0.051792

131	0.0	49.8	36.000000	1.864500	0.051792
131	0.0	49.8	54.000000	2.486000	0.046037
131	0.0	49.8	72.000000	3.107500	0.043160
131	0.0	49.8	90.000000	3.977600	0.044196
131	0.0	49.8	108.000000	4.785550	0.044311
131	0.0	49.8	125.999992	5.593500	0.044393
131	0.0	49.8	144.000000	6.277150	0.043591
131	0.0	49.8	161.999985	7.147250	0.044119
131	0.0	49.8	180.000000	8.079500	0.044886

10% w/w COAL-ANTHRACENE OIL - COOLING

28	10.0	40.4	22.500000	5.763000	0.256133
28	10.0	40.4	45.000000	10.848000	0.241067
28	10.0	40.4	67.500000	16.271999	0.241067
28	10.0	40.4	90.000000	21.695999	0.241067
28	10.0	40.4	112.500000	27.119999	0.241067
28	10.0	40.4	135.000000	32.543999	0.241067
28	10.0	40.4	157.500000	37.629002	0.238914
28	10.0	40.4	180.000000	43.052998	0.239183
28	10.0	40.4	202.499985	48.138000	0.237719
28	10.0	40.4	225.000000	52.883999	0.235040
132	10.0	126.0	67.500000	0.423750	0.006278
132	10.0	126.0	90.000000	0.593250	0.006592
132	10.0	126.0	112.500000	0.762750	0.006780
132	10.0	126.0	123.750008	0.847500	0.006848
132	10.0	126.0	135.000000	0.932250	0.006906
132	10.0	126.0	146.250000	1.050900	0.007186
132	10.0	126.0	157.500000	1.186500	0.007533
132	10.0	126.0	180.000000	1.356000	0.007533
132	10.0	126.0	202.499985	1.525500	0.007533
132	10.0	126.0	225.000000	1.779750	0.007910
133	10.0	106.8	36.000000	0.339000	0.009417
133	10.0	106.8	54.000000	0.423750	0.007847
133	10.0	106.8	72.000000	0.508500	0.007062
133	10.0	106.8	90.000000	0.644100	0.007157
133	10.0	106.8	108.000000	0.847500	0.007847
133	10.0	106.8	125.999992	1.017000	0.008071
133	10.0	106.8	135.000000	1.101750	0.008161
133	10.0	106.8	144.000000	1.220400	0.008475
133	10.0	106.8	161.999985	1.491600	0.009207
133	10.0	106.8	180.000000	1.695000	0.009417
134	10.0	87.5	36.000000	0.423750	0.011771
134	10.0	87.5	54.000000	0.508500	0.009417
134	10.0	87.5	72.000000	0.627150	0.008710
134	10.0	87.5	90.000000	0.762750	0.008475
134	10.0	87.5	108.000000	0.898350	0.008318
134	10.0	87.5	125.999992	1.067850	0.008475
134	10.0	87.5	135.000000	1.152600	0.008538
134	10.0	87.5	144.000000	1.237350	0.008593
134	10.0	87.5	161.999985	1.525500	0.009417
134	10.0	87.5	180.000000	1.898400	0.010547
135	10.0	67.5	18.000000	0.339000	0.018833
135	10.0	67.5	36.000000	0.621500	0.017264
135	10.0	67.5	54.000000	0.847500	0.015694
135	10.0	67.5	72.000000	1.130000	0.015694
135	10.0	67.5	90.000000	1.412500	0.015694
135	10.0	67.5	108.000000	1.695000	0.015694
135	10.0	67.5	125.999992	1.977500	0.015694
135	10.0	67.5	144.000000	2.260000	0.015694
135	10.0	67.5	161.999985	2.542500	0.015694
135	10.0	67.5	180.000000	2.825000	0.015694
136	10.0	49.0	18.000000	1.130000	0.062778
136	10.0	49.0	36.000000	1.977500	0.054931
136	10.0	49.0	54.000000	2.966250	0.054931
136	10.0	49.0	72.000000	3.729000	0.051792
136	10.0	49.0	90.000000	4.661250	0.051792
136	10.0	49.0	108.000000	5.508750	0.051007
136	10.0	49.0	125.999992	6.497500	0.051567
136	10.0	49.0	144.000000	7.345000	0.051007
136	10.0	49.0	161.999985	8.249000	0.050920
136	10.0	49.0	180.000000	9.181250	0.051007

30% w/w COAL-ANTHRACENE OIL - COOLING

41	30.0	122.2	31.500002	0.565000	0.017937
41	30.0	122.2	63.000004	0.904000	0.014349
41	30.0	122.2	94.500000	1.243000	0.013153
41	30.0	122.2	126.000008	1.582000	0.012556
41	30.0	122.2	141.749985	1.751500	0.012356
41	30.0	122.2	157.500000	1.921000	0.012197
41	30.0	122.2	173.250015	2.147000	0.012392
41	30.0	122.2	189.000000	2.373000	0.012556
41	30.0	122.2	204.750000	2.599000	0.012694
41	30.0	122.2	220.499985	2.938000	0.013324
42	30.0	97.8	31.500002	0.762750	0.024214
42	30.0	97.8	63.000004	1.356000	0.021524
42	30.0	97.8	94.500000	1.949250	0.020627
42	30.0	97.8	126.000008	2.542500	0.020179
42	30.0	97.8	157.500000	3.220500	0.020448
42	30.0	97.8	189.000000	3.898500	0.020627
42	30.0	97.8	220.499985	4.576500	0.020755
42	30.0	97.8	252.000015	5.339250	0.021187
42	30.0	97.8	283.499969	6.102000	0.021524
42	30.0	97.8	315.000000	6.949500	0.022062
43	30.0	68.5	31.500002	2.034000	0.064571
43	30.0	68.5	63.000004	3.559500	0.056500
43	30.0	68.5	94.500000	5.424000	0.057397
43	30.0	68.5	126.000008	7.119000	0.056500
43	30.0	68.5	157.500000	8.814000	0.055962
43	30.0	68.5	189.000000	10.509001	0.055603
43	30.0	68.5	220.499985	12.373501	0.056116
43	30.0	68.5	252.000015	14.068501	0.055827
43	30.0	68.5	283.499969	15.933000	0.056201
43	30.0	68.5	315.000000	17.797499	0.056500
44	30.0	49.5	31.500002	7.514500	0.238556
44	30.0	49.5	63.000004	14.633500	0.232278
44	30.0	49.5	94.500000	21.357002	0.226000
44	30.0	49.5	126.000008	28.080500	0.222861
44	30.0	49.5	157.500000	35.199501	0.223489
44	30.0	49.5	189.000000	42.714005	0.226000
44	30.0	49.5	220.499985	49.833000	0.226000
44	30.0	49.5	252.000015	56.952000	0.226000
44	30.0	49.5	283.499969	64.466499	0.227395
44	30.0	49.5	315.000000	71.189995	0.226000
45	30.0	30.2	13.500001	10.735000	0.795185
45	30.0	30.2	27.000002	19.775000	0.732407
45	30.0	30.2	40.500000	28.814999	0.711481
45	30.0	30.2	54.000004	37.290001	0.690556
45	30.0	30.2	67.500000	46.329998	0.686370
45	30.0	30.2	81.000000	54.805000	0.676605
45	30.0	30.2	94.499992	63.279999	0.669630
45	30.0	30.2	108.000008	71.754997	0.664398
45	30.0	30.2	121.499992	80.229996	0.660329
45	30.0	30.2	135.000000	87.574997	0.648704

50% w/w COAL-ANTHRACENE OIL - COOLING

58	50.0	116.3	22.500000	4.068000	0.180800
58	50.0	116.3	45.000000	7.684000	0.170756
58	50.0	116.3	67.500000	11.300000	0.167407
58	50.0	116.3	90.000000	14.690000	0.163222
58	50.0	116.3	112.500000	18.080000	0.160711
58	50.0	116.3	135.000000	21.696001	0.160711
58	50.0	116.3	157.500000	25.086000	0.159276
58	50.0	116.3	180.000000	28.476000	0.158200
58	50.0	116.3	202.499985	31.865999	0.157363
58	50.0	116.3	225.000000	34.803997	0.154684
59	50.0	89.8	22.500000	8.644500	0.384200
59	50.0	89.8	45.000000	16.780500	0.372900
59	50.0	89.8	67.500000	24.408001	0.361600
59	50.0	89.8	90.000000	32.035500	0.355950
59	50.0	89.8	112.500000	38.646000	0.343520
59	50.0	89.8	135.000000	44.747997	0.331467
59	50.0	89.8	157.500000	51.866997	0.329314
59	50.0	89.8	180.000000	58.477501	0.324875
59	50.0	89.8	202.499985	65.596497	0.323933
59	50.0	89.8	225.000000	72.715500	0.323180
60	50.0	69.5	9.000000	13.560000	1.506667
60	50.0	69.5	18.000000	25.424999	1.412500
60	50.0	69.5	27.000000	36.724998	1.360185
60	50.0	69.5	36.000000	46.329998	1.286944
60	50.0	69.5	45.000000	55.935001	1.243000
60	50.0	69.5	54.000000	64.974998	1.203241
60	50.0	69.5	62.999996	73.449997	1.165873
60	50.0	69.5	72.000000	81.360001	1.130000
60	50.0	69.5	80.999992	88.705002	1.095124
60	50.0	69.5	90.000000	96.050003	1.067222
61	50.0	53.5	2.250000	10.170000	4.520000
61	50.0	53.5	4.500000	19.775000	4.394444
61	50.0	53.5	9.000000	37.290001	4.143333
61	50.0	53.5	11.250000	45.200001	4.017778
61	50.0	53.5	13.500000	52.544998	3.892222
61	50.0	53.5	18.000000	66.669998	3.703889
61	50.0	53.5	22.500000	79.665001	3.540667
61	50.0	53.5	27.000000	91.529999	3.390000
61	50.0	53.5	31.499998	102.830002	3.264445
61	50.0	53.5	35.549999	113.000000	3.178622

BITUMEN HEATING

62	0.0	25.3	0.360000	9.605000	26.680555
62	0.0	25.3	0.720000	19.775000	27.465277
62	0.0	25.3	1.080000	29.944998	27.726849
62	0.0	25.3	1.440000	40.114998	27.857635
62	0.0	25.3	1.800000	49.719997	27.622219
62	0.0	25.3	2.160000	59.889996	27.726849
62	0.0	25.3	2.520000	70.060005	27.801590
62	0.0	25.3	2.880000	79.665001	27.661457
62	0.0	25.3	3.240000	89.834999	27.726854
62	0.0	25.3	3.600000	99.439995	27.622219
63	0.0	34.5	1.125000	10.170000	9.040000
63	0.0	34.5	2.250000	20.340000	9.040000
63	0.0	34.5	3.375000	30.510002	9.040001
63	0.0	34.5	4.500000	41.810001	9.291111
63	0.0	34.5	5.625000	51.415001	9.140445
63	0.0	34.5	6.750000	62.150002	9.207408
63	0.0	34.5	7.875000	72.320000	9.183493
63	0.0	34.5	9.000000	83.055000	9.228333
63	0.0	34.5	10.124999	93.224998	9.207408
63	0.0	34.5	11.250000	102.830002	9.140445
64	0.0	40.8	3.150000	10.170000	3.228571
64	0.0	40.8	6.300000	20.905001	3.318254
64	0.0	40.8	9.450000	31.639999	3.348148
64	0.0	40.8	12.600000	42.375000	3.363095
64	0.0	40.8	15.750000	53.109997	3.372063
64	0.0	40.8	18.900000	63.844997	3.378042
64	0.0	40.8	22.049999	74.580002	3.382313
64	0.0	40.8	25.200001	85.315002	3.385516
64	0.0	40.8	28.349998	95.485001	3.368078
64	0.0	40.8	31.500000	105.655006	3.354127
65	0.0	49.0	6.750000	10.170000	1.506667
65	0.0	49.0	13.500001	19.775000	1.464815
65	0.0	49.0	20.250000	29.379999	1.450864
65	0.0	49.0	27.000002	38.985001	1.443889
65	0.0	49.0	33.750000	49.154999	1.456444
65	0.0	49.0	40.500000	58.759998	1.450864
65	0.0	49.0	47.249996	68.365005	1.446879
65	0.0	49.0	54.000004	77.970001	1.443889
65	0.0	49.0	60.749996	87.574997	1.441564
65	0.0	49.0	67.500000	97.180000	1.439704
66	0.0	61.2	13.500001	9.040000	0.669630
66	0.0	61.2	27.000002	18.080000	0.669630
66	0.0	61.2	40.500000	27.120001	0.669630
66	0.0	61.2	54.000004	36.724998	0.680093
66	0.0	61.2	67.500000	45.764999	0.678000
66	0.0	61.2	81.000000	54.805000	0.676605
66	0.0	61.2	94.499992	64.410004	0.681587
66	0.0	61.2	108.000008	74.014999	0.685324
66	0.0	61.2	121.499992	83.055000	0.683580
66	0.0	61.2	135.000000	92.659996	0.686370
67	0.0	71.2	24.750002	9.040000	0.365252
67	0.0	71.2	49.500004	18.080000	0.365252
67	0.0	71.2	74.250000	27.120001	0.365253
67	0.0	71.2	99.000008	36.160000	0.365252
67	0.0	71.2	123.750000	45.200001	0.365253
67	0.0	71.2	148.500000	54.805000	0.369057
67	0.0	71.2	173.249985	63.844997	0.368514
67	0.0	71.2	198.000015	72.884995	0.368106
67	0.0	71.2	222.749985	81.925003	0.367789
67	0.0	71.2	247.500000	90.400002	0.365253
68	0.0	82.0	31.500002	7.119000	0.226000

68	0.0	82.0	63.000004	13.842500	0.219722
68	0.0	82.0	94.500000	20.961498	0.221815
68	0.0	82.0	126.000008	28.080500	0.222861
68	0.0	82.0	157.500000	35.199501	0.223489
68	0.0	82.0	189.000000	42.318501	0.223907
68	0.0	82.0	220.499985	49.437500	0.224206
68	0.0	82.0	252.000015	56.556496	0.224431
68	0.0	82.0	283.499969	63.675503	0.224605
68	0.0	82.0	315.000000	70.399002	0.223489
69	0.0	93.2	31.500002	4.520000	0.143492
69	0.0	93.2	63.000004	8.757501	0.139008
69	0.0	93.2	94.500000	12.995000	0.137513
69	0.0	93.2	126.000008	17.232500	0.136766
69	0.0	93.2	157.500000	21.752499	0.138111
69	0.0	93.2	189.000000	25.990000	0.137513
69	0.0	93.2	220.499985	30.510002	0.138367
69	0.0	93.2	252.000015	35.030003	0.139008
69	0.0	93.2	283.499969	39.267498	0.138510
69	0.0	93.2	315.000000	43.787498	0.139008
70	0.0	109.8	31.500002	2.542500	0.080714
70	0.0	109.8	63.000004	4.576500	0.072643
70	0.0	109.8	94.500000	6.441000	0.068159
70	0.0	109.8	126.000008	8.475000	0.067262
70	0.0	109.8	157.500000	10.509001	0.066724
70	0.0	109.8	189.000000	12.543000	0.066365
70	0.0	109.8	220.499985	14.746500	0.066878
70	0.0	109.8	252.000015	16.780500	0.066589
70	0.0	109.8	283.499969	18.983999	0.066963
70	0.0	109.8	315.000000	21.018002	0.066724
71	0.0	123.0	31.500002	1.582000	0.050222
71	0.0	123.0	63.000004	3.051000	0.048429
71	0.0	123.0	94.500000	4.520000	0.047831
71	0.0	123.0	126.000008	5.989000	0.047532
71	0.0	123.0	157.500000	7.571000	0.048070
71	0.0	123.0	189.000000	9.153000	0.048429
71	0.0	123.0	220.499985	10.735001	0.048685
71	0.0	123.0	252.000015	12.317000	0.048877
71	0.0	123.0	283.499969	14.012001	0.049425
71	0.0	123.0	315.000000	15.707000	0.049863
72	0.0	131.8	27.000002	1.130000	0.041852
72	0.0	131.8	54.000004	2.147000	0.039759
72	0.0	131.8	81.000000	3.164000	0.039062
72	0.0	131.8	108.000008	4.181000	0.038713
72	0.0	131.8	135.000000	5.198000	0.038504
72	0.0	131.8	162.000000	6.215000	0.038364
72	0.0	131.8	188.999985	7.232000	0.038265
72	0.0	131.8	216.000015	8.249001	0.038190
72	0.0	131.8	242.999985	9.379000	0.038597
72	0.0	131.8	270.000000	10.509000	0.038922
73	0.0	142.0	27.000002	0.762750	0.028250
73	0.0	142.0	54.000004	1.610250	0.029819
73	0.0	142.0	81.000000	2.373000	0.029296
73	0.0	142.0	108.000008	3.135750	0.029035
73	0.0	142.0	135.000000	3.983250	0.029506
73	0.0	142.0	162.000000	4.830750	0.029819
73	0.0	142.0	188.999985	5.678250	0.030044
73	0.0	142.0	216.000015	6.525750	0.030212
73	0.0	142.0	242.999985	7.458000	0.030691
73	0.0	142.0	270.000000	8.390250	0.031075
74	0.0	151.0	27.000002	0.678000	0.025111
74	0.0	151.0	54.000004	1.356000	0.025111

74	0.0	151.0	81.000000	1.949250	0.024065
74	0.0	151.0	108.000008	2.627250	0.024326
74	0.0	151.0	135.000000	3.305250	0.024483
74	0.0	151.0	162.000000	3.983250	0.024588
74	0.0	151.0	188.999985	4.661250	0.024663
74	0.0	151.0	216.000015	5.339250	0.024719
74	0.0	151.0	242.999985	6.102000	0.025111
74	0.0	151.0	270.000000	6.864750	0.025425

10% w/w COAL-BITUMEN - HEATING

80	10.0	24.8	0.225000	10.170000	45.199997
80	10.0	24.8	0.450000	20.340000	45.199997
80	10.0	24.8	0.675000	30.510002	45.200001
80	10.0	24.8	0.900000	39.549999	43.944443
80	10.0	24.8	1.125000	49.154999	43.693333
80	10.0	24.8	1.350000	58.759998	43.525925
80	10.0	24.8	1.575000	68.930000	43.765083
80	10.0	24.8	1.800000	77.404999	43.002777
80	10.0	24.8	2.025000	86.445000	42.688892
80	10.0	24.8	2.250000	95.485001	42.437778
81	10.0	34.0	0.675000	10.170000	15.066667
81	10.0	34.0	1.350000	20.340000	15.066667
81	10.0	34.0	2.025000	29.944998	14.787653
81	10.0	34.0	2.700000	38.985001	14.438889
81	10.0	34.0	3.375000	49.154999	14.564445
81	10.0	34.0	4.050000	58.195000	14.369135
81	10.0	34.0	4.725000	67.235008	14.229631
81	10.0	34.0	5.400000	76.840004	14.229630
81	10.0	34.0	6.075000	85.879997	14.136625
81	10.0	34.0	6.750000	94.919998	14.062222
82	10.0	44.0	2.025000	11.300000	5.580247
82	10.0	44.0	4.050000	21.469999	5.301234
82	10.0	44.0	6.075000	31.639999	5.208230
82	10.0	44.0	8.100000	42.375000	5.231481
82	10.0	44.0	10.125000	52.544998	5.189630
82	10.0	44.0	12.150001	62.715000	5.161728
82	10.0	44.0	14.174999	72.320000	5.101940
82	10.0	44.0	16.200001	82.490005	5.091975
82	10.0	44.0	18.224998	92.095001	5.053224
82	10.0	44.0	20.250000	101.699997	5.022222
83	10.0	52.9	4.050000	10.170000	2.511111
83	10.0	52.9	8.100000	19.775000	2.441358
83	10.0	52.9	12.150001	29.379999	2.418107
83	10.0	52.9	16.200001	38.985001	2.406482
83	10.0	52.9	20.250000	48.590000	2.399506
83	10.0	52.9	24.300001	58.195000	2.394856
83	10.0	52.9	28.349998	67.800003	2.391535
83	10.0	52.9	32.400002	76.840004	2.371605
83	10.0	52.9	36.449997	86.445000	2.371605
83	10.0	52.9	40.500000	94.919998	2.343704
84	10.0	63.0	9.000000	11.300000	1.255556
84	10.0	63.0	18.000000	22.035000	1.224167
84	10.0	63.0	27.000000	32.770000	1.213704
84	10.0	63.0	36.000000	43.504997	1.208472
84	10.0	63.0	45.000000	53.675003	1.192778
84	10.0	63.0	54.000000	63.844997	1.182315
84	10.0	63.0	62.999996	74.580002	1.183810
84	10.0	63.0	72.000000	84.750000	1.177083
84	10.0	63.0	80.999992	95.485001	1.178827
84	10.0	63.0	90.000000	105.089996	1.167667
85	10.0	73.8	16.200001	10.170000	0.627778
85	10.0	73.8	32.400002	19.775000	0.610339
85	10.0	73.8	48.600002	29.944998	0.616152
85	10.0	73.8	64.800003	40.114998	0.619059
85	10.0	73.8	81.000000	50.285000	0.620802
85	10.0	73.8	97.200005	60.455002	0.621965
85	10.0	73.8	113.399994	70.625000	0.622795
85	10.0	73.8	129.600006	80.794998	0.623418
85	10.0	73.8	145.799988	90.965004	0.623903
85	10.0	73.8	162.000000	100.570000	0.620802
86	10.0	83.2	20.250000	8.136000	0.401778

86	10.0	83.2	40.500000	15.820001	0.390617
86	10.0	83.2	60.750000	23.955999	0.394337
86	10.0	83.2	81.000000	32.091999	0.396198
86	10.0	83.2	101.250000	40.680000	0.401778
86	10.0	83.2	121.500000	48.816006	0.401778
86	10.0	83.2	141.750000	56.952000	0.401778
86	10.0	83.2	162.000000	65.540001	0.404568
86	10.0	83.2	182.249985	73.676003	0.404258
86	10.0	83.2	202.500000	81.812004	0.404010
87	10.0	91.4	22.500000	6.780000	0.301333
87	10.0	91.4	45.000000	12.656000	0.281244
87	10.0	91.4	67.500000	19.436001	0.287941
87	10.0	91.4	90.000000	25.764000	0.286267
87	10.0	91.4	112.500000	32.091999	0.285262
87	10.0	91.4	135.000000	38.872002	0.287941
87	10.0	91.4	157.500000	46.556000	0.295594
87	10.0	91.4	180.000000	51.980000	0.288778
87	10.0	91.4	202.499985	58.759998	0.290173
87	10.0	91.4	225.000000	65.540001	0.291289
88	10.0	101.2	22.500000	5.424000	0.241067
88	10.0	101.2	45.000000	10.509001	0.233533
88	10.0	101.2	67.500000	15.594000	0.231022
88	10.0	101.2	90.000000	20.679001	0.229767
88	10.0	101.2	112.500000	26.102999	0.232027
88	10.0	101.2	135.000000	31.527000	0.233533
88	10.0	101.2	157.500000	36.951000	0.234610
88	10.0	101.2	180.000000	42.375000	0.235417
88	10.0	101.2	202.499985	48.476997	0.239393
88	10.0	101.2	225.000000	53.223003	0.236547
89	10.0	114.2	22.500000	3.164000	0.140622
89	10.0	114.2	45.000000	5.876000	0.130578
89	10.0	114.2	67.500000	8.588000	0.127230
89	10.0	114.2	90.000000	11.300000	0.125556
89	10.0	114.2	112.500000	14.012001	0.124551
89	10.0	114.2	135.000000	16.950001	0.125556
89	10.0	114.2	157.500000	19.662001	0.124838
89	10.0	114.2	180.000000	22.600000	0.125556
89	10.0	114.2	202.499985	25.537998	0.126114
89	10.0	114.2	225.000000	28.476000	0.126560
90	10.0	128.4	22.500000	2.034000	0.090400
90	10.0	128.4	45.000000	3.616000	0.080356
90	10.0	128.4	67.500000	5.311000	0.078681
90	10.0	128.4	90.000000	6.893000	0.076589
90	10.0	128.4	112.500000	8.588000	0.076338
90	10.0	128.4	135.000000	10.283001	0.076170
90	10.0	128.4	157.500000	12.091001	0.076768
90	10.0	128.4	180.000000	13.786000	0.076589
90	10.0	128.4	202.499985	15.481000	0.076449
90	10.0	128.4	225.000000	17.289000	0.076840
91	10.0	144.6	22.500000	1.582000	0.070311
91	10.0	144.6	45.000000	2.712000	0.060267
91	10.0	144.6	67.500000	4.068000	0.060267
91	10.0	144.6	90.000000	5.424000	0.060267
91	10.0	144.6	112.500000	6.780000	0.060267
91	10.0	144.6	135.000000	8.136000	0.060267
91	10.0	144.6	157.500000	9.492000	0.060267
91	10.0	144.6	180.000000	10.848001	0.060267
91	10.0	144.6	202.499985	12.317000	0.060825
91	10.0	144.6	225.000000	13.673000	0.060769

30% w/w COAL-BITUMEN - HEATING

97	30.0	24.8	0.090000	10.735000	119.277771
97	30.0	24.8	0.180000	20.340000	113.000000
97	30.0	24.8	0.270000	31.075001	115.092590
97	30.0	24.8	0.360000	40.680000	113.000000
97	30.0	24.8	0.450000	50.285000	111.744438
97	30.0	24.8	0.540000	60.455002	111.953705
97	30.0	24.8	0.630000	72.320000	114.793648
97	30.0	24.8	0.720000	80.229996	111.430542
97	30.0	24.8	0.810000	91.529999	113.000008
97	30.0	24.8	0.900000	100.004997	111.116661
98	30.0	33.0	0.315000	11.865000	37.666668
98	30.0	33.0	0.630000	23.164999	36.769840
98	30.0	33.0	0.945000	35.595001	37.666668
98	30.0	33.0	1.260000	46.895000	37.218254
98	30.0	33.0	1.575000	58.759998	37.307938
98	30.0	33.0	1.890000	70.060005	37.068787
98	30.0	33.0	2.205000	81.360001	36.897961
98	30.0	33.0	2.520000	92.659996	36.769840
98	30.0	33.0	2.835000	103.959999	36.670197
98	30.0	33.0	3.118500	113.000000	36.235371
99	30.0	41.0	0.810000	10.735000	13.253086
99	30.0	41.0	1.620000	21.469999	13.253086
99	30.0	41.0	2.430000	32.205002	13.253087
99	30.0	41.0	3.240000	42.939999	13.253086
99	30.0	41.0	4.050000	53.109997	13.113581
99	30.0	41.0	4.860000	63.844997	13.136830
99	30.0	41.0	5.670000	74.580002	13.153440
99	30.0	41.0	6.480000	84.750000	13.078704
99	30.0	41.0	7.289999	94.919998	13.020576
99	30.0	41.0	8.099999	103.959999	12.834569
100	30.0	50.9	2.025000	10.735000	5.301234
100	30.0	50.9	4.050000	21.469999	5.301234
100	30.0	50.9	6.075000	32.205002	5.301235
100	30.0	50.9	8.100000	43.504997	5.370987
100	30.0	50.9	10.125000	54.240002	5.357037
100	30.0	50.9	12.150001	64.974998	5.347736
100	30.0	50.9	14.174999	75.144997	5.301235
100	30.0	50.9	16.200001	85.879997	5.301234
100	30.0	50.9	18.224998	96.050003	5.270234
100	30.0	50.9	20.250000	105.655006	5.217531
101	30.0	65.8	6.750000	10.735000	1.590370
101	30.0	65.8	13.500001	22.035000	1.632222
101	30.0	65.8	20.250000	33.334999	1.646173
101	30.0	65.8	27.000002	45.200001	1.674074
101	30.0	65.8	33.750000	56.500000	1.674074
101	30.0	65.8	40.500000	67.800003	1.674074
101	30.0	65.8	47.249996	79.099998	1.674074
101	30.0	65.8	54.000004	89.834999	1.663611
101	30.0	65.8	60.749996	100.570000	1.655473
101	30.0	65.8	67.500000	110.740005	1.640593
102	30.0	75.2	13.500001	11.300000	0.837037
102	30.0	75.2	27.000002	22.600000	0.837037
102	30.0	75.2	40.500000	33.900002	0.837037
102	30.0	75.2	54.000004	45.200001	0.837037
102	30.0	75.2	67.500000	56.500000	0.837037
102	30.0	75.2	81.000000	67.800003	0.837037
102	30.0	75.2	94.499992	79.099998	0.837037
102	30.0	75.2	108.000008	90.400002	0.837037
102	30.0	75.2	121.499992	101.699997	0.837037
102	30.0	75.2	135.000000	111.870003	0.828667
	30.0	88.6	15.750001	8.475000	0.538095

103	30.0	88.6	31.500002	16.950001	0.538095
103	30.0	88.6	47.250000	25.990000	0.550053
103	30.0	88.6	63.000004	35.030003	0.556032
103	30.0	88.6	78.750000	44.070000	0.559619
103	30.0	88.6	94.500000	52.544998	0.556032
103	30.0	88.6	110.249992	61.585003	0.558594
103	30.0	88.6	126.000008	70.625000	0.560516
103	30.0	88.6	141.749985	79.665001	0.562011
103	30.0	88.6	157.500000	88.139999	0.559619
104	30.0	96.9	20.250000	8.475000	0.418519
104	30.0	96.9	40.500000	15.820000	0.390617
104	30.0	96.9	60.750000	24.295000	0.399918
104	30.0	96.9	81.000000	32.205002	0.397593
104	30.0	96.9	101.250000	40.114998	0.396197
104	30.0	96.9	121.500000	48.025002	0.395268
104	30.0	96.9	141.750000	56.500000	0.398589
104	30.0	96.9	162.000000	64.974998	0.401080
104	30.0	96.9	182.249985	72.884995	0.399918
104	30.0	96.9	202.500000	80.229996	0.396197
105	30.0	109.2	29.250002	6.780000	0.231795
105	30.0	109.2	58.500004	12.995000	0.222137
105	30.0	109.2	87.750000	19.775000	0.225356
105	30.0	109.2	117.000008	26.554998	0.226966
105	30.0	109.2	131.624985	29.944998	0.227502
105	30.0	109.2	146.250000	33.334999	0.227932
105	30.0	109.2	175.500000	41.245003	0.235014
105	30.0	109.2	204.749985	46.895000	0.229035
105	30.0	109.2	234.000015	53.675003	0.229380
105	30.0	109.2	248.625000	56.500000	0.227250
106	30.0	120.9	27.000002	5.876000	0.217630
106	30.0	120.9	54.000004	10.396000	0.192519
106	30.0	120.9	81.000000	14.464000	0.178568
106	30.0	120.9	108.000008	19.436001	0.179963
106	30.0	120.9	135.000000	23.955999	0.177452
106	30.0	120.9	162.000000	28.927999	0.178568
106	30.0	120.9	188.999985	33.900002	0.179365
106	30.0	120.9	216.000015	38.872002	0.179963
106	30.0	120.9	242.999985	43.843998	0.180428
106	30.0	120.9	270.000000	48.816006	0.180800
107	30.0	129.8	27.000002	3.672500	0.136018
107	30.0	129.8	54.000004	7.062500	0.130787
107	30.0	129.8	81.000000	10.735000	0.132531
107	30.0	129.8	108.000008	14.407499	0.133403
107	30.0	129.8	135.000000	18.362499	0.136019
107	30.0	129.8	162.000000	22.317501	0.137762
107	30.0	129.8	188.999985	26.272499	0.139008
107	30.0	129.8	216.000015	30.227501	0.139942
107	30.0	129.8	242.999985	34.465000	0.141831
107	30.0	129.8	270.000000	38.137501	0.141250
108	30.0	141.0	27.000002	3.051000	0.113000
108	30.0	141.0	54.000004	5.763000	0.106722
108	30.0	141.0	81.000000	8.475000	0.104630
108	30.0	141.0	108.000008	11.356500	0.105153
108	30.0	141.0	135.000000	14.238000	0.105467
108	30.0	141.0	162.000000	17.289000	0.106722
108	30.0	141.0	188.999985	20.170502	0.106722
108	30.0	141.0	216.000015	23.221500	0.107507
108	30.0	141.0	242.999985	26.272499	0.108117
108	30.0	141.0	270.000000	29.154001	0.107978

50% w/w COAL-BITUMEN - HEATING

113	50.0	47.5	0.135000	12.429999	92.074066
113	50.0	47.5	0.270000	23.164999	85.796288
113	50.0	47.5	0.405000	32.770000	80.913574
113	50.0	47.5	0.540000	41.245003	76.379631
113	50.0	47.5	0.675000	49.154999	72.822220
113	50.0	47.5	0.810000	58.759998	72.543205
113	50.0	47.5	0.945000	66.669998	70.550262
113	50.0	47.5	1.080000	75.144997	69.578697
113	50.0	47.5	1.215000	81.925003	67.427994
113	50.0	47.5	1.350000	89.270004	66.125931
114	50.0	56.0	0.405000	16.950001	41.851852
114	50.0	56.0	0.810000	24.859999	30.691357
114	50.0	56.0	1.215000	36.160000	29.761316
114	50.0	56.0	1.620000	46.329998	28.598764
114	50.0	56.0	2.025000	57.064999	28.180248
114	50.0	56.0	2.430000	67.235008	27.668726
114	50.0	56.0	2.835000	77.404999	27.303352
114	50.0	56.0	3.240000	87.009995	26.854937
114	50.0	56.0	3.645000	96.050003	26.351170
114	50.0	56.0	4.050000	105.089996	25.948149
115	50.0	69.7	0.900000	12.995000	14.438889
115	50.0	69.7	1.800000	24.295000	13.497222
115	50.0	69.7	2.700000	35.595001	13.183333
115	50.0	69.7	3.600000	46.329998	12.869443
115	50.0	69.7	4.500000	57.064999	12.681110
115	50.0	69.7	5.400000	66.669998	12.346295
115	50.0	69.7	6.300000	76.275002	12.107143
115	50.0	69.7	7.200000	85.879997	11.927777
115	50.0	69.7	8.099999	94.919998	11.718519
115	50.0	69.7	9.000000	102.830002	11.425556
116	50.0	78.8	1.485000	13.560000	9.131313
116	50.0	78.8	2.970000	24.859999	8.370370
116	50.0	78.8	4.455000	36.724998	8.243546
116	50.0	78.8	5.940000	47.459999	7.989899
116	50.0	78.8	7.425000	57.629997	7.761616
116	50.0	78.8	8.910000	67.800003	7.609428
116	50.0	78.8	10.395000	76.840004	7.392016
116	50.0	78.8	11.880000	86.445000	7.276515
116	50.0	78.8	13.364999	95.485001	7.144408
116	50.0	78.8	14.849999	103.394997	6.962626
117	50.0	87.6	2.475000	13.560000	5.478788
117	50.0	87.6	4.950000	25.424999	5.136363
117	50.0	87.6	7.425000	36.724998	4.946127
117	50.0	87.6	9.900001	48.025002	4.851010
117	50.0	87.6	12.375000	58.195000	4.702626
117	50.0	87.6	14.850000	68.365005	4.603704
117	50.0	87.6	17.324999	77.970001	4.500433
117	50.0	87.6	19.800001	87.009995	4.394444
117	50.0	87.6	22.274998	97.745003	4.388104
117	50.0	87.6	24.750000	104.525009	4.223233
118	50.0	106.8	6.750000	12.995000	1.925185
118	50.0	106.8	13.500001	23.730000	1.757778
118	50.0	106.8	20.250000	34.465000	1.701975
118	50.0	106.8	27.000002	45.200001	1.674074
118	50.0	106.8	33.750000	55.370003	1.640593
118	50.0	106.8	40.500000	65.540001	1.618272
118	50.0	106.8	47.249996	75.144997	1.590370
118	50.0	106.8	54.000004	84.750000	1.569444
118	50.0	106.8	60.749996	94.354996	1.553169
118	50.0	106.8	67.500000	103.394997	1.531778
119	50.0	118.4	8.100000	13.560000	1.674074

119	50.0	118.4	16.200001	25.424999	1.569444
119	50.0	118.4	24.300001	36.160000	1.488066
119	50.0	118.4	32.400002	47.459999	1.464815
119	50.0	118.4	40.500000	57.629997	1.422963
119	50.0	118.4	48.600002	67.235008	1.383436
119	50.0	118.4	56.699997	76.840004	1.355203
119	50.0	118.4	64.800003	86.445000	1.334028
119	50.0	118.4	72.899994	96.050003	1.317558
119	50.0	118.4	81.000000	103.959999	1.283457
120	50.0	128.0	10.350000	12.429999	1.200966
120	50.0	128.0	20.700001	23.730000	1.146377
120	50.0	128.0	31.050001	35.030003	1.128180
120	50.0	128.0	41.400002	45.200001	1.091787
120	50.0	128.0	46.574997	49.719997	1.067526
120	50.0	128.0	51.750000	54.805000	1.059034
120	50.0	128.0	56.925003	59.889996	1.052086
120	50.0	128.0	62.100002	65.540001	1.055395
120	50.0	128.0	72.449997	74.580002	1.029400
120	50.0	128.0	82.800003	84.184998	1.016727
121	50.0	138.0	13.500001	12.429999	0.920741
121	50.0	138.0	27.000002	23.730000	0.878889
121	50.0	138.0	33.750000	29.944998	0.887259
121	50.0	138.0	40.500000	35.030003	0.864938
121	50.0	138.0	54.000004	45.764999	0.847500
121	50.0	138.0	67.500000	56.500000	0.837037
121	50.0	138.0	81.000000	65.540001	0.809136
121	50.0	138.0	94.499992	76.275002	0.807143
121	50.0	138.0	121.499992	96.615005	0.795185
121	50.0	138.0	135.000000	104.525009	0.774259
122	50.0	147.0	18.000000	13.560000	0.753333
122	50.0	147.0	36.000000	25.424999	0.706250
122	50.0	147.0	54.000000	36.724998	0.680093
122	50.0	147.0	72.000000	48.025002	0.667014
122	50.0	147.0	90.000000	58.759998	0.652889
122	50.0	147.0	108.000000	69.494995	0.643472
122	50.0	147.0	125.999992	79.665001	0.632262
122	50.0	147.0	144.000000	90.400002	0.627778
122	50.0	147.0	161.999985	101.134995	0.624290
122	50.0	147.0	180.000000	110.740005	0.615222

BITUMEN - COOLING

75	0.0	131.8	27.000002	1.243000	0.046037
75	0.0	131.8	54.000004	2.373000	0.043944
75	0.0	131.8	81.000000	3.616000	0.044642
75	0.0	131.8	108.000008	4.859000	0.044991
75	0.0	131.8	135.000000	5.989000	0.044363
75	0.0	131.8	162.000000	7.345000	0.045340
75	0.0	131.8	188.999985	8.588000	0.045439
75	0.0	131.8	216.000015	9.831000	0.045514
75	0.0	131.8	242.999985	11.187000	0.046037
75	0.0	131.8	270.000000	12.543000	0.046456
76	0.0	114.5	27.000002	2.542500	0.094167
76	0.0	114.5	54.000004	5.085000	0.094167
76	0.0	114.5	81.000000	7.458000	0.092074
76	0.0	114.5	108.000008	10.000499	0.092597
76	0.0	114.5	135.000000	12.543000	0.092911
76	0.0	114.5	162.000000	15.085500	0.093120
76	0.0	114.5	188.999985	17.628000	0.093270
76	0.0	114.5	216.000015	20.170502	0.093382
76	0.0	114.5	242.999985	22.712999	0.093469
76	0.0	114.5	270.000000	25.425001	0.094167
77	0.0	93.8	27.000002	6.780000	0.251111
77	0.0	93.8	54.000004	13.559999	0.251111
77	0.0	93.8	81.000000	20.000998	0.246926
77	0.0	93.8	108.000008	26.781000	0.247972
77	0.0	93.8	135.000000	33.561001	0.248600
77	0.0	93.8	162.000000	40.341003	0.249019
77	0.0	93.8	188.999985	47.120998	0.249317
77	0.0	93.8	216.000015	53.901001	0.249542
77	0.0	93.8	242.999985	60.341999	0.248321
77	0.0	93.8	270.000000	67.122002	0.248600
78	0.0	73.4	11.250000	9.040000	0.803556
78	0.0	73.4	22.500000	18.080000	0.803556
78	0.0	73.4	33.750000	27.685001	0.820296
78	0.0	73.4	45.000000	36.724998	0.816111
78	0.0	73.4	56.250000	45.764999	0.813600
78	0.0	73.4	67.500000	55.370003	0.820296
78	0.0	73.4	78.750000	64.410004	0.817905
78	0.0	73.4	90.000000	73.449997	0.816111
78	0.0	73.4	101.249992	83.055000	0.820296
78	0.0	73.4	112.500000	91.529999	0.813600
79	0.0	53.9	2.250000	9.040000	4.017778
79	0.0	53.9	4.500000	18.080000	4.017778
79	0.0	53.9	6.750000	27.120001	4.017778
79	0.0	53.9	9.000000	36.160000	4.017778
79	0.0	53.9	11.250000	45.200001	4.017778
79	0.0	53.9	13.500000	54.240002	4.017778
79	0.0	53.9	15.749999	63.279999	4.017778
79	0.0	53.9	18.000000	72.320000	4.017778
79	0.0	53.9	20.249998	81.360001	4.017778
79	0.0	53.9	22.500000	89.270004	3.967556

10% w/w COAL-BITUMEN - COOLING

92	10.0	125.6	22.500000	2.373000	0.105467
92	10.0	125.6	45.000000	4.746000	0.105467
92	10.0	125.6	67.500000	7.119000	0.105467
92	10.0	125.6	90.000000	9.492000	0.105467
92	10.0	125.6	112.500000	11.865000	0.105467
92	10.0	125.6	135.000000	14.238000	0.105467
92	10.0	125.6	157.500000	16.441500	0.104390
92	10.0	125.6	180.000000	18.814501	0.104525
92	10.0	125.6	202.499985	21.187500	0.104630
92	10.0	125.6	225.000000	23.730000	0.105467
93	10.0	97.3	20.250000	9.605000	0.474321
93	10.0	97.3	40.500000	19.775000	0.488272
93	10.0	97.3	60.750000	29.944998	0.492922
93	10.0	97.3	81.000000	40.114998	0.495247
93	10.0	97.3	101.250000	50.285000	0.496642
93	10.0	97.3	121.500000	61.020004	0.502222
93	10.0	97.3	141.750000	71.190002	0.502222
93	10.0	97.3	162.000000	81.360001	0.502222
93	10.0	97.3	182.249985	91.529999	0.502222
93	10.0	97.3	202.500000	101.699997	0.502222
94	10.0	79.4	6.750000	11.300000	1.674074
94	10.0	79.4	13.500001	22.035000	1.632222
94	10.0	79.4	20.250000	32.770000	1.618272
94	10.0	79.4	27.000002	44.070000	1.632222
94	10.0	79.4	33.750000	55.370003	1.640593
94	10.0	79.4	40.500000	66.669998	1.646173
94	10.0	79.4	47.249996	77.404999	1.638201
94	10.0	79.4	54.000004	88.139999	1.632222
94	10.0	79.4	60.749996	98.875000	1.627572
94	10.0	79.4	67.500000	109.044991	1.615481
95	10.0	56.1	1.125000	10.170000	9.040000
95	10.0	56.1	2.250000	20.340000	9.040000
95	10.0	56.1	3.375000	30.510002	9.040001
95	10.0	56.1	4.500000	40.680000	9.040000
95	10.0	56.1	5.625000	50.849998	9.040000
95	10.0	56.1	6.750000	60.455002	8.956297
95	10.0	56.1	7.875000	70.060005	8.896509
95	10.0	56.1	9.000000	79.665001	8.851666
95	10.0	56.1	10.124999	89.834999	8.872593
95	10.0	56.1	11.250000	98.875000	8.788889
96	10.0	32.7	0.180000	14.690000	81.611107
96	10.0	32.7	0.360000	28.250000	78.472221
96	10.0	32.7	0.540000	42.939999	79.518517
96	10.0	32.7	0.720000	56.500000	78.472221
96	10.0	32.7	0.810000	64.410004	79.518532
96	10.0	32.7	0.900000	71.190002	79.099998
96	10.0	32.7	1.080000	86.445000	80.041664
96	10.0	32.7	1.170000	92.659996	79.196579
96	10.0	32.7	1.260000	98.875000	78.472221
96	10.0	32.7	1.440000	113.000000	78.472221

30% w/w COAL-BITUMEN - COOLING

109	30.0	115.4	27.000002	8.475000	0.313889
109	30.0	115.4	54.000004	16.950001	0.313889
109	30.0	115.4	81.000000	25.424999	0.313889
109	30.0	115.4	108.000008	34.465000	0.319120
109	30.0	115.4	135.000000	42.939999	0.318074
109	30.0	115.4	162.000000	51.415001	0.317377
109	30.0	115.4	188.999985	59.889996	0.316878
109	30.0	115.4	216.000015	68.365005	0.316505
109	30.0	115.4	242.999985	77.404999	0.318539
109	30.0	115.4	270.000000	85.879997	0.318074
110	30.0	96.2	9.000000	9.040000	1.004444
110	30.0	96.2	18.000000	18.080000	1.004444
110	30.0	96.2	27.000000	27.685001	1.025370
110	30.0	96.2	36.000000	36.724998	1.020139
110	30.0	96.2	45.000000	45.764999	1.017000
110	30.0	96.2	54.000000	54.805000	1.014907
110	30.0	96.2	62.999996	63.844997	1.013413
110	30.0	96.2	72.000000	71.754997	0.996597
110	30.0	96.2	80.999992	80.794998	0.997469
110	30.0	96.2	90.000000	89.270004	0.991889
111	30.0	73.0	1.800000	9.040000	5.022222
111	30.0	73.0	3.600000	18.645000	5.179167
111	30.0	73.0	5.400000	27.685001	5.126852
111	30.0	73.0	7.200000	37.290001	5.179167
111	30.0	73.0	9.000000	46.329998	5.147778
111	30.0	73.0	10.800000	55.370003	5.126852
111	30.0	73.0	12.599999	64.410004	5.111905
111	30.0	73.0	14.400001	73.449997	5.100694
111	30.0	73.0	16.199999	82.490005	5.091976
111	30.0	73.0	18.000000	90.965004	5.053611
112	30.0	49.0	0.180000	9.605000	53.361111
112	30.0	49.0	0.360000	19.775000	54.930553
112	30.0	49.0	0.540000	28.814999	53.361107
112	30.0	49.0	0.720000	38.420002	53.361111
112	30.0	49.0	0.900000	47.459999	52.733330
112	30.0	49.0	1.080000	57.064999	52.837959
112	30.0	49.0	1.260000	65.540001	52.015873
112	30.0	49.0	1.440000	75.144997	52.184025
112	30.0	49.0	1.620000	84.184998	51.966053
112	30.0	49.0	1.800000	92.659996	51.477772

50% w/w COAL-BITUMEN - COOLING

123	50.0	127.2	6.750000	13.560000	2.008889
123	50.0	127.2	13.500001	25.424999	1.883333
123	50.0	127.2	20.250000	36.724998	1.813580
123	50.0	127.2	27.000002	47.459999	1.757778
123	50.0	127.2	33.750000	57.629997	1.707556
123	50.0	127.2	40.500000	67.800003	1.674074
123	50.0	127.2	47.249996	77.404999	1.638201
123	50.0	127.2	54.000004	87.009995	1.611296
123	50.0	127.2	60.749996	96.050003	1.581070
123	50.0	127.2	67.500000	104.525009	1.548519
124	50.0	108.0	2.250000	12.429999	5.524444
124	50.0	108.0	4.500000	23.164999	5.147778
124	50.0	108.0	6.750000	33.900002	5.022223
124	50.0	108.0	9.000000	43.504997	4.833889
124	50.0	108.0	11.250000	53.109997	4.720889
124	50.0	108.0	13.500000	62.150002	4.603704
124	50.0	108.0	15.749999	71.190002	4.520000
124	50.0	108.0	18.000000	80.229996	4.457222
124	50.0	108.0	20.249998	88.139999	4.352593
124	50.0	108.0	22.500000	96.050003	4.268889
125	50.0	88.5	1.125000	15.255001	13.560001
125	50.0	88.5	2.250000	27.685001	12.304445
125	50.0	88.5	3.375000	40.680000	12.053333
125	50.0	88.5	4.500000	51.980000	11.551111
125	50.0	88.5	5.625000	64.410004	11.450667
125	50.0	88.5	6.750000	74.580002	11.048889
125	50.0	88.5	7.875000	85.879997	10.905397
125	50.0	88.5	9.000000	96.050003	10.672222
125	50.0	88.5	10.124999	106.219994	10.490865
125	50.0	88.5	10.912500	113.000000	10.355097
126	50.0	68.5	0.180000	12.995000	72.194443
126	50.0	68.5	0.360000	25.424999	70.624992
126	50.0	68.5	0.540000	37.290001	69.055557
126	50.0	68.5	0.720000	47.459999	65.916664
126	50.0	68.5	0.900000	57.629997	64.033325
126	50.0	68.5	1.080000	67.800003	62.777779
126	50.0	68.5	1.260000	76.840004	60.984131
126	50.0	68.5	1.440000	86.445000	60.031246
126	50.0	68.5	1.620000	95.485001	58.941364
126	50.0	68.5	1.800000	103.959999	57.755554